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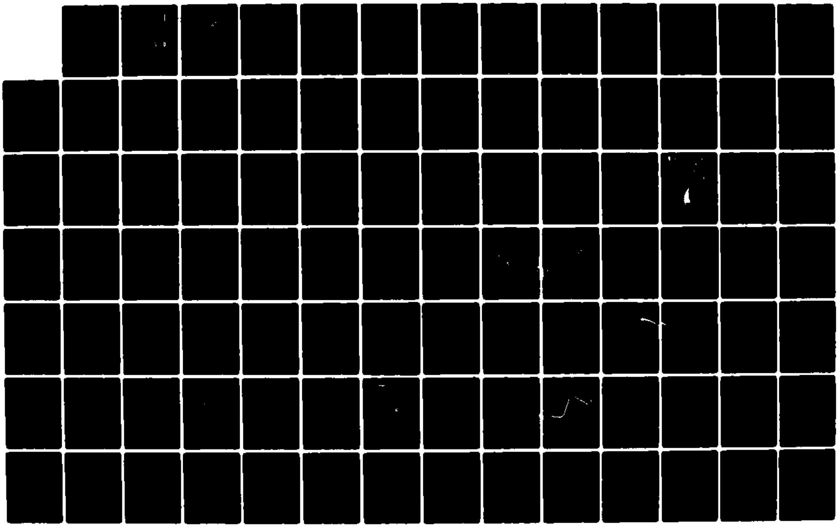

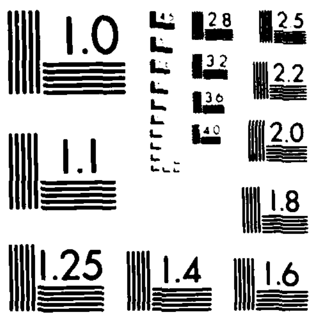

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NATIONAL BUREAU OF STANDARDS 1963-A

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FINAL CONTRACT REPORT

ENGINEERING AND ENVIRONMENTAL STUDY OF DDT CONTAMINATION OF HUNTSVILLE SPRING BRANCH, INDIAN CREEK, AND ADJACENT LANDS AND WATERS, WHEELER RESERVOIR, ALABAMA

NOVEMBER 1980

VOLUME 1 OF 3
SUMMARY

PREPARED FOR:
UNITED STATES ARMY CORPS OF ENGINEERS
MOBILE DISTRICT
CONTRACT NO. DACW01-79-C-0224

SUBMITTED BY:
WATER AND AIR RESEARCH, INC.
GAINESVILLE, FLORIDA 32602

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DDT-1,1'-(2,2,2 - Trichloroethylidene) bis (4-chlorobenzene)
Tennessee River Water Analysis Wheeler Reservoir
Huntsville Spring Branch Pesticide Residues Chemical Analysis
Indian Creek

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

DDT contamination in northeast Alabama near Triana, in the Tennessee River system including Wilson, Wheeler, and Guntersville Reservoirs has occurred because wastes containing DDT residues (DDTR) have migrated to receiving streams. In the area DDTR levels in fish exceed the 5 ppm limit set by the FDA for edible portions of fish. Evidence of human DDT contamination has been found in persons routinely consuming the fish.

In the spring of 1979 an engineering and environmental study began to determine whether or not corrective action is required, and if so, the technical

approach to such corrective action. The nature and extent of contamination have been defined, and engineering, economic, and environmental feasibility of alternative solutions have been evaluated. Study included extensive field and laboratory work. Data were gathered on fish, sediment, water, macroinvertebrates, plankton, aquatic plants, mammals, bi ls, and reptiles in the area. Additionally, efforts were made to secure all prior existing data.

Analysis of data provided quantification of pollutant transport by biological (food chain) and physical (mostly hydrologic) processes. Data collected during the current study have been compared to historical data to determine extent of sediment contamination and rate of movement downstream. Groundwater transport has been evaluated.

Principal study findings include:

1. An extensive amount of DDTR exists in reservoir sediments.

2. DDTR is being moved slowly downstream.

3. Fish, particularly channel catfish, are contaminated with DDTR throughout Wheeler Reservoir.

4. Contamination of aquatic organisms, results from low levels of DDTR that now exist in water and/or sediment.

5. Contamination of aquatic organisms also appears to be caused by migration of contaminated fish to relatively uncontaminated areas.

Remedial alternatives for mitigation were compared to the Natural Restoration Alternative, which is to allow clean-up by natural processes. Alternatives are based on various means of isolating DDTR from the environment and include: (1) dredging or removing the contaminated sediments and placing them in a secure landfill, (2) covering the contaminated sediments in place, and/or (3) bypassing flow around the contaminated area. For the six final alternatives, details regarding engineering and economic feasibilities and environmental and regulatory impacts are presented. Time required for remedial results is also discussed.

FINAL CONTRACT REPORT

ENGINEERING AND ENVIRONMENTAL STUDY OF DDT CONTAMINATION OF HUNTSVILLE SPRING BRANCH, INDIAN CREEK, AND ADJACENT LANDS AND WATERS, WHEELER RESERVOIR, ALABAMA

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PREPARED FOR:
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SUBMITTED BY:
WATER AND AIR RESEARCH, INC.
GAINESVILLE, FLORIDA 32602

EXECUTIVE SUMMARY

1.0 INTRODUCTION

This report deals with DDTR contamination in northeast Alabama in the Tennessee River system from Mile 260 to 375 which includes Wilson, Wheeler, and Guntersville Reservoirs. The primary area of interest is the Huntsville Spring Branch - Indian Creek (HSB-IC) tributary system which enters the Tennessee River (TR) at Mile 321. From 1947 to 1970 a privately operated DDT plant on Redstone Arsenal discharged waste containing DDT residues (DDT + DDD + DDE), commonly referred to as DDTR. A major impact of these residues has been the contamination of certain fish species to DDTR levels exceeding the 5 ppm limit set by the Food and Drug Administration (FDA) for edible portions of fish.

In the spring of 1979 an engineering and environmental study was initiated by the Department of the Army, with study management by the U.S. Army Corps of Engineers, to establish the basis for determining whether corrective action is required, and if so, the engineering approach to such corrective action. This contract report to the Corps defines the nature and extent of the contamination and evaluates the engineering, economic, and environmental feasibility of a broad range of alternative solutions. The study included extensive field and laboratory work performed largely by the Tennessee Valley Authority (TVA). Data were gathered on fish, sediment, water, macroinvertebrates, plankton, aquatic plants, mammals, birds, and reptiles in the area. Additionally, efforts were made to secure all prior existing data relevant to this subject.

One area specifically excluded from this study was human health effects. That aspect of the problem is being investigated by the Center for Disease Control in Atlanta.

2.0 EXTENT OF THE PROBLEM

Historically, wastes from the DDT manufacturing plant flowed down a ditch to HSB at about Mile 5.4. Records exist indicating contamination of sediments in HSB to levels exceeding 10,000 ppm as early as 1963. In 1970 analysis of fish from the area showed some samples from both Wilson and Wheeler Reservoirs exceeding the 5 ppm criteria. In the early 1950's, bird population estimates for Wheeler National Wildlife Refuge, which includes the contaminated area, showed declines of certain species. However, since many of the species were migratory, it cannot be definitely concluded that this contamination caused the decline.

In the late 1970's much more extensive information was gathered regarding the extent of contamination in sediments, water, plants, and animals. It is estimated that some 837 tons of DDTR currently exists in the sediments of HSB and IC. About 47 percent of the DDTR is in the top 6 inches of sediment. On an areal basis, about 96 percent of the DDTR is in HSB upstream of Dodd Road between Miles 2.4 and 5.4. Another 3 percent is in the lower 2.4 miles of HSB and the final 1 percent is in the lower 5 miles of IC. About 99.9 percent of the DDTR is in the bottom sediments with the remaining amount in the water, plants, and animals.

DDTR is being slowly moved downstream through the HSB-IC system and out into the TR. Very low, but detectable quantities of DDTR exist in TR sediments downstream of IC.

Fish surveys made in 1979 and 1980 indicate that fish, particularly channel catfish, in the IC area have DDTR concentrations well above the 5 ppm level, many greater than 50 ppm. It appears that channel catfish are the most contaminated species and that they may have DDTR levels above 5 ppm in essentially all parts of Wheeler Reservoir. Smallmouth buffalo are contaminated to a lesser degree but at some locations had greater than 5 ppm DDTR. Largemouth bass generally had less than 5 ppm DDT although some individual fish had concentrations greater than 10 ppm. White crappie, white bass, and bluegill generally appear to have levels less than 5 ppm but may exceed limits in the IC area.

Two factors seem to be causing high levels of DDTR in catfish and smallmouth buffalo in the TR. First, the level of DDTR in the TR downstream of IC, although low, is sufficient to cause an elevated base level of contamination. In channel catfish this base appears to be near the 5 ppm criteria. Second, migration of fish from the more contaminated area of IC results in high concentrations at other sites above what would be produced by local contamination.

Elevated levels of DDTR have been found in birds and other animals in the area and particularly in those living near HSB and IC.

In summary it appears that:

1) an extensive amount of DDTR is in the sediments of HSB and IC

2) this DDTR is being slowly moved through the HSB-IC system and out into the TR

3) fish, particularly channel catfish, are highly contaminated with DDTR in IC and throughout Wheeler Reservoir they have DDTR levels above the 5 ppm criteria

4) contamination of fish in the TR results from low levels of DDTR that now exist in the water and/or sediment downstream of IC

5) contamination of fish in the TR also appears to be caused by the migration of contaminated fish to areas relatively uncontaminated.

3.0 ALTERNATIVES FOR MITIGATION OF THE PROBLEM

A full range of alternatives for mitigation of this problem was investigated. All can be compared with the Natural Restoration Alternative which is to allow the situation to be cleaned up by natural processes. Unfortunately, it appears that this alternative has little or no chance of significantly improving the situation in any reasonable time period.

Action alternatives are all based on various means of isolating the DDTR from the environment. This could be accomplished by (1) dredging or removing the contaminated sediments and placing them in a secure landfill (2) covering the contaminated sediments in place, and/or (3) bypassing flow around the contaminated area. Details regarding the various alternatives are presented in the following tables. Costs of all alternatives would be lowered if a decision were made to isolate a smaller fraction of the DDTR.

Even if an action alternative is selected for implementation, complete recovery of the system to the point that channel catfish in the TR will have DDTR levels less than 5 ppm will take a number of years. It will take several years to complete any of the action alternatives. Following that, it could take as long as 1 to 30 years for the DDTR already in the TR to degrade or become isolated.

Table 1 . Alternatives for Mitigation of DDT Contamination

Alternative	Major Actions Implemented
A. Natural Restoration	o let natural processes mitigate contamination o extensive monitoring to determine whether system is improving, remaining stable, or deteriorating
B. Dredging and Disposal	o construct dredged material disposal area o dredge channel sediments from HSB Mile 5.6 to IC Mile 0.0 and 260 acres of overbank sediments between Dodd and Patton Roads to a depth of 3 feet
C. Out-of-Basin Diversion and Removal of Contaminated Sediments	o divert HSB upstream from contaminated area directly to the TR o implement all actions listed for Alternative B under reduced flow conditions
D. Out-of-Basin Diversion and Containment of Contaminated Sediments	o divert HSB upstream from contaminated area directly to the TR o construct dikes to isolate contaminated sediments upstream of Dodd Road from surface water flow o construct dredged material disposal area o dredge channel sediments from Dodd Road to IC Mile 0.0 to a depth of 3 feet o cover and stabilize channel sediments and 260 acres of overbank sediments upstream of Dodd Road
E. Within-Basin Diversion and Removal of Contaminated Sediments	o divert HSB around the highly contaminated area between HSB Miles 3.9 and 5.6 o construct dike around the highly contaminated area o implement all actions listed under Alternative B. Highly contaminated sediments would be removed under zero flow or dry conditions.
F. Within-Basin Diversion and Containment of Contaminated Sediments	o divert HSB around the highly contaminated area between HSB Miles 3.9 and 5.6 o construct dike around the highly contaminated area o construct dredged material disposal area o dredge channel sediments from HSB Mile 3.9 to IC Mile 0.0 to a depth of 3 feet o cover and stabilize channel sediments and 185 acres of overbank sediments within diked area
Alternate: Use Containment Area for Disposal of Dredged Material	o Same as above except dredged material would be disposed of within the diked highly contaminated area.

Table 2 . Estimated Level of Mitigation, Predicted Impacts, and Estimated Costs Associated With Proposed Alternatives.

Alter-native	Estimated % DDTR			Predicted Adverse Environmental Impacts	Est. Cost millions
	Remove	Cover	Total		
A	0	0	0	(1) DDTR continues to move down HSB to IC and the TR (2) Fish and other biota continue to have elevated DDTR levels	0.6/yr
B	99.3	0	99.3	(1) Significantly alter 313 acres wetland, 228 acres aquatic habitat (2) Lose "edge" habitat along dredged stream (3) Lose Aufwuch communities and snag habitats in dredged stream (4) Some short-term water quality loss	86.8
C	99.3	0	99.3	(1) Significantly alter 684 acres wetland, 495 acres upland, and 313 acres aquatic habitat (2) Dredging impacts (2)-(4) listed under Alternative B (3) Increase in suspended solids and nutrients loading to the TR via the diversion channel	137
D	4.4	94.9	99.3	(1) Significantly alter 701 acres wetland, 521 acres upland, and 313 acres aquatic habitat (2) Dredging impacts (2)-(4) listed under Alternative B for dredging downstream from Dodd Road (3) Increase in suspended solids and nutrient loading to the TR via the diversion channel (4) Drier habitat in HSB between Patton and Dodd Roads	130

Table 2. Estimated Level of Mitigation, Predicted Impacts, and Estimated Costs Associated With Proposed Alternatives, (Continued)

Alternative	Estimated % DDTR			Predicted Adverse Environmental Impacts	Est. Cost millions
	Remove	Cover	Total		
E	99.3	0	99.3	(1) Significantly alter 619 acres wetland, 348 acres upland, and 338 acres aquatic habitat (2) Dredging impacts (2)-(4) listed under Alternative B for dredging downstream from HSB Mile 3.9 (3) Increase in suspended solids and nutrient loading to IC via the diversion channel	106
F	8.3	91.0	99.3	(1) Significantly alter 612 acres wetland, 348 acres upland, and 338 acres aquatic habitat (2) Dredging impacts (2)-(4) listed under Alternative B for dredging downstream from HSB Mile 3.9 (3) Increase in suspended solids, nutrient loading to IC via the diversion channel (4) Drier habitat in HSB between Miles 3.9 and 5.6	93.0
F*	8.3	91.4	99.7	(1) Significantly alter 612 acres wetland, 161 acres upland, and 338 acres aquatic habitat (2) Dredging impacts (2)-(4) listed under Alternative B for dredging downstream from HSB Mile 3.9 (3) Increase in suspended solids and nutrient loading to IC via the diversion channel (4) Drier habitat in HSB between Miles 3.9 and 5.6	88.9

* Alternative F with option to use diked contaminated area for disposal of dredged material.

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PREFACE

Volume 1 of this report contains a complete summary of the current situation and a description of alternatives for mitigating the problem. Volume 2 contains three appendices which present in detail the properties of DDT, a description of the current situation, and the alternatives for mitigation. Volume 3 contains the data collected during the study and the quality assurance documents pertaining to that data.

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1.0 INTRODUCTION

This report deals with DDTR contamination in northeast Alabama in the Tennessee River system from Mile Point 260 to 375 which includes Wilson, Wheeler, and Guntersville Reservoirs (see Figures 1, 2, and 3). The primary area of interest is the Huntsville Spring Branch - Indian Creek (HSB-IC) tributary system which enters the Tennessee River at Mile Point 321 (see Figure 4). From 1947 to 1970 a privately operated DDT plant on Redstone Arsenal discharged waste into HSB containing DDT residues. Sediments in the area still contain high levels of DDT residues (DDT + DDD + DDE), commonly referred to as DDTR. A major impact of these residues has been the contamination of certain fish species to DDTR levels exceeding the 5 ppm limit set by the Food and Drug Administration for edible portions of fish.

In the spring of 1979, an engineering and environmental study was initiated by the Department of the Army, with study management by the U.S. Army Corps of Engineers, to establish the basis for determining whether corrective action is required, and if so, the engineering approach to such corrective action. This contract report to the Corps defines the nature and extent of the contamination and evaluates the engineering, economic, and environmental feasibilty of a broad range of alternative solutions. The study included extensive field and laboratory work performed largely by the Tennessee Valley Authority (TVA). Data were gathered on fish, sediment, water, macroinvertebrates, plankton, aquatic plants, mammals, birds, and reptiles in the area. Additionally, efforts were made to secure all prior existing data relevant to this subject.

One area that was specifically excluded from this study was human health effects. That aspect of the problem is being investigated by the Center for Disease Control office in Atlanta.

During the course of this study the possibility of PCB contamination in the study area has been investigated independently by the Environmental Protection Agency, the U.S. Army, NASA (Marshall Space Flight Center), and the Center for Disease Control. Findings to date indicate no relationship between the original source of DDT and PCB's. Based on this finding, there is no discussion of PCB's included in this report.

This main report section is a summary of the more detailed appendices that follow. As these appendices are fully referenced, no sources are cited in this section.

2.0 HISTORICAL DEVELOPMENT OF PROBLEM

2.1 MANUFACTURING PLANT HISTORY

In 1947 the Calabama Chemical Company began manufacture of DDT at facilities leased from Redstone Arsenal. The plant discharged wastes to a drainage ditch which in turn discharged to Huntsville Spring Branch at about Mile 5.4. No definitive records have been found regarding

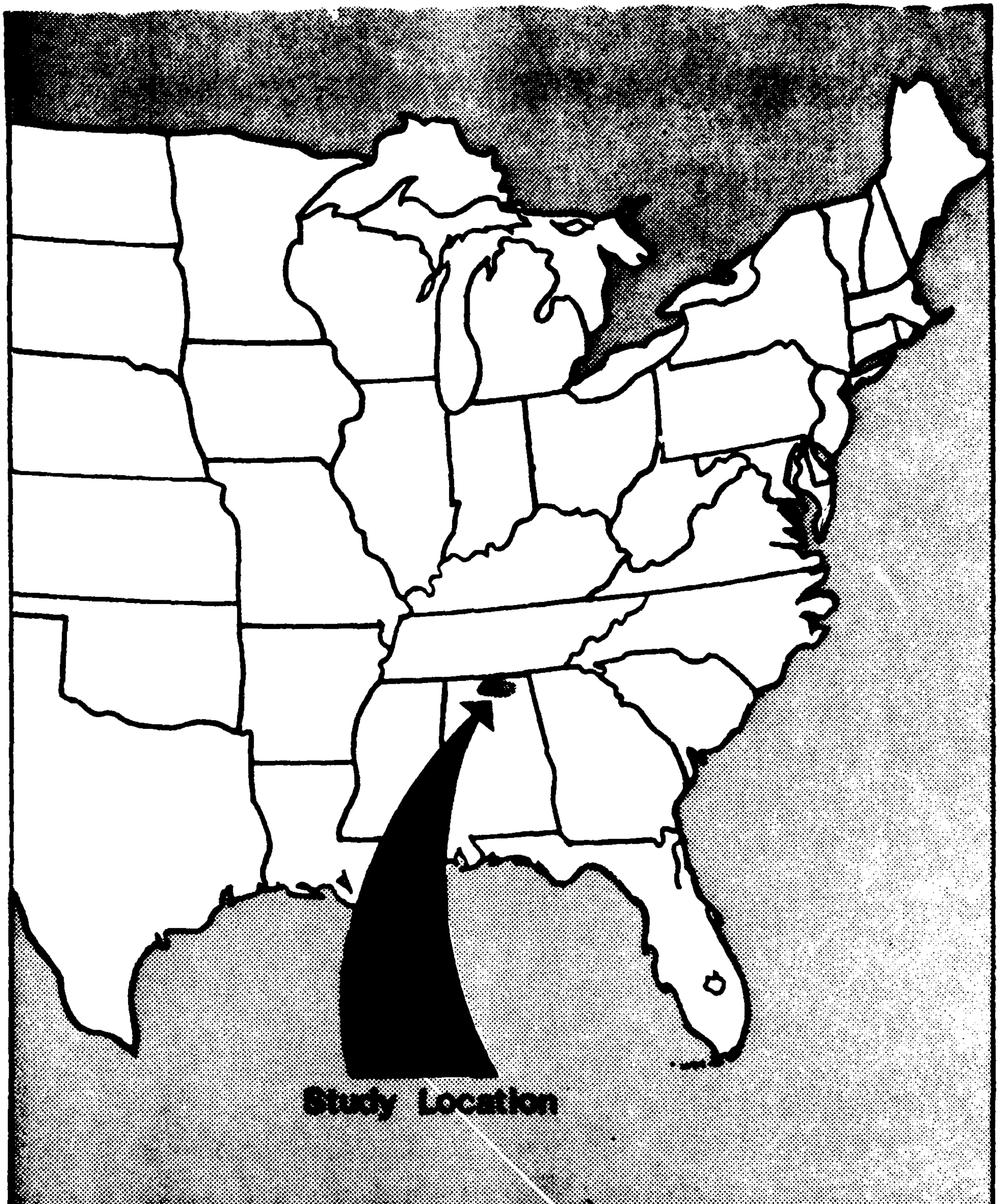


FIGURE 1. Study Location SOURCE: WATER AND AIR RESEARCH, INC., 1980	U.S. ARMY CORPS OF ENGINEERS, MOBILE DISTRICT Engineering and Environmental Study Of DDT Contamination of Huntsville Spring Branch, Indian Creek, and Adjacent Lands and Waters Wheeler Reservoir, Alabama

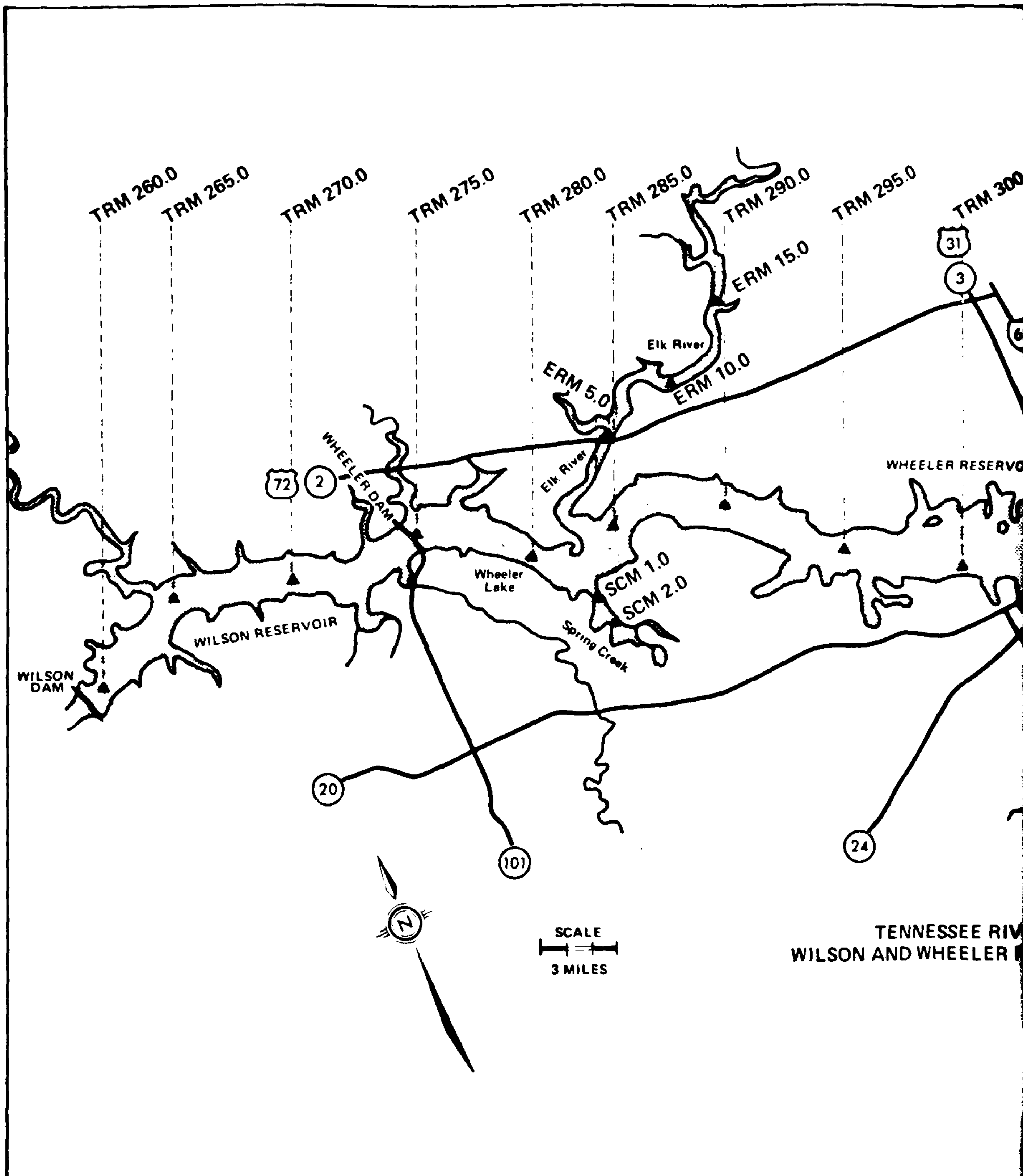
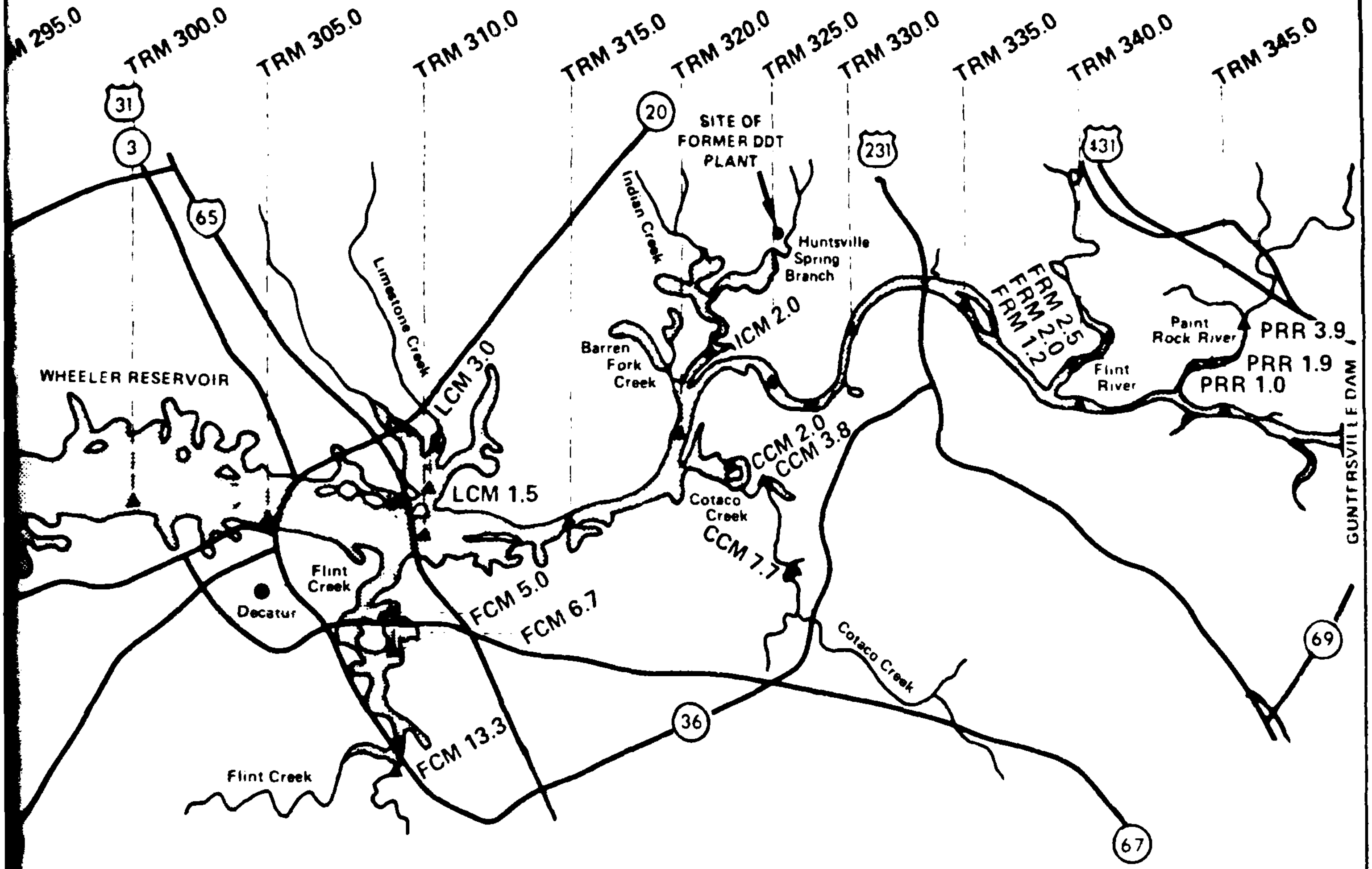


FIGURE 2. Tennessee River, Wilson and Wheeler Reservoirs

SOURCE WATER AND AIR RESEARCH, INC., 1980



CCM	–	COTACO CREEK MILE
ERM	–	ELK RIVER MILE
FCM	–	FLINT CREEK MILE
FRM	–	FLINT RIVER MILE
ICM	–	INDIAN CREEK MILE
LCM	–	LIMESTONE CREEK MILE
PRR	–	PAINT ROCK RIVER
SCM	–	SPRING CREEK MILE
TRM	–	TENNESSEE RIVER MILE

TENNESSEE RIVER,
AND WHEELER RESERVOIRS

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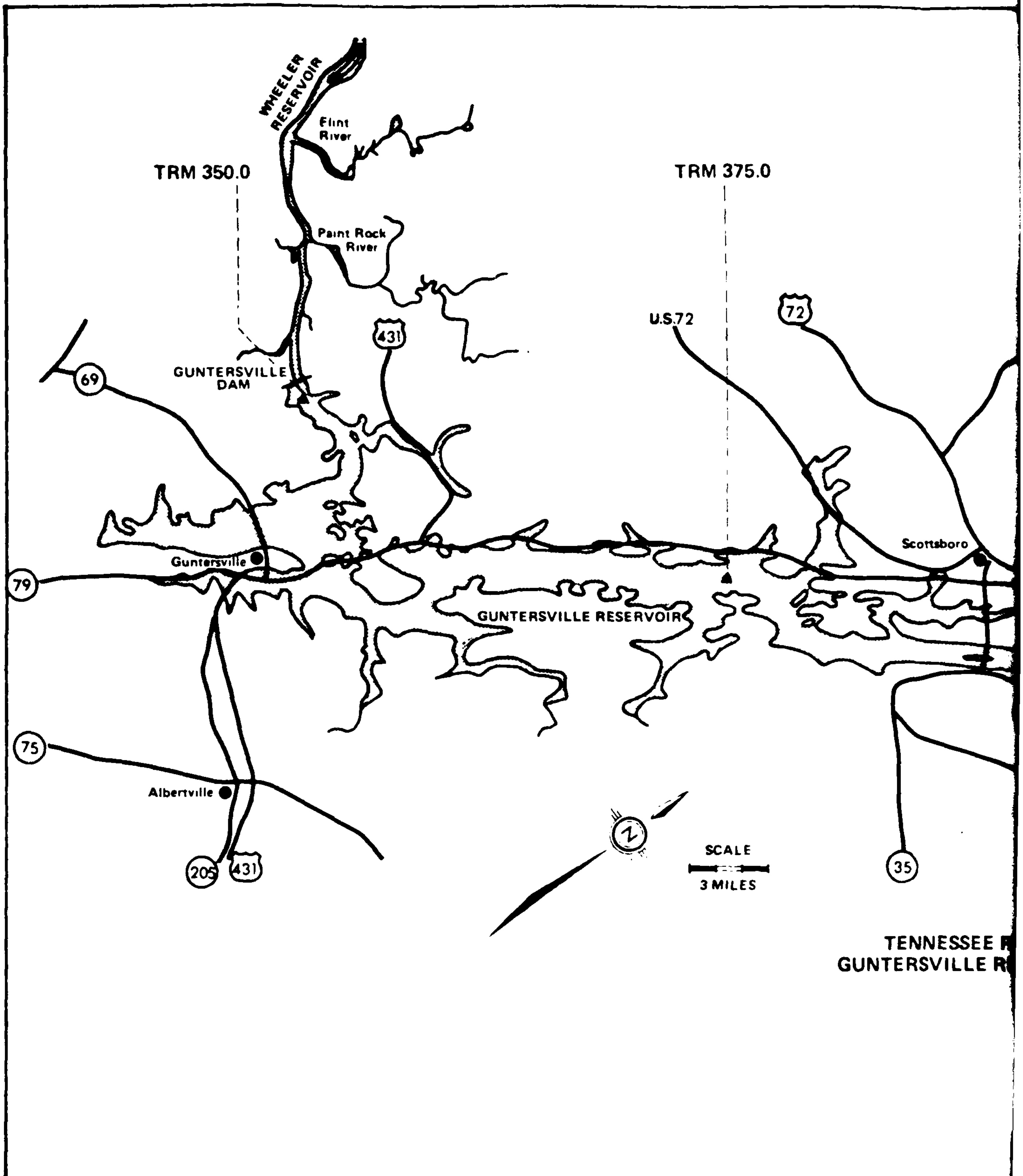
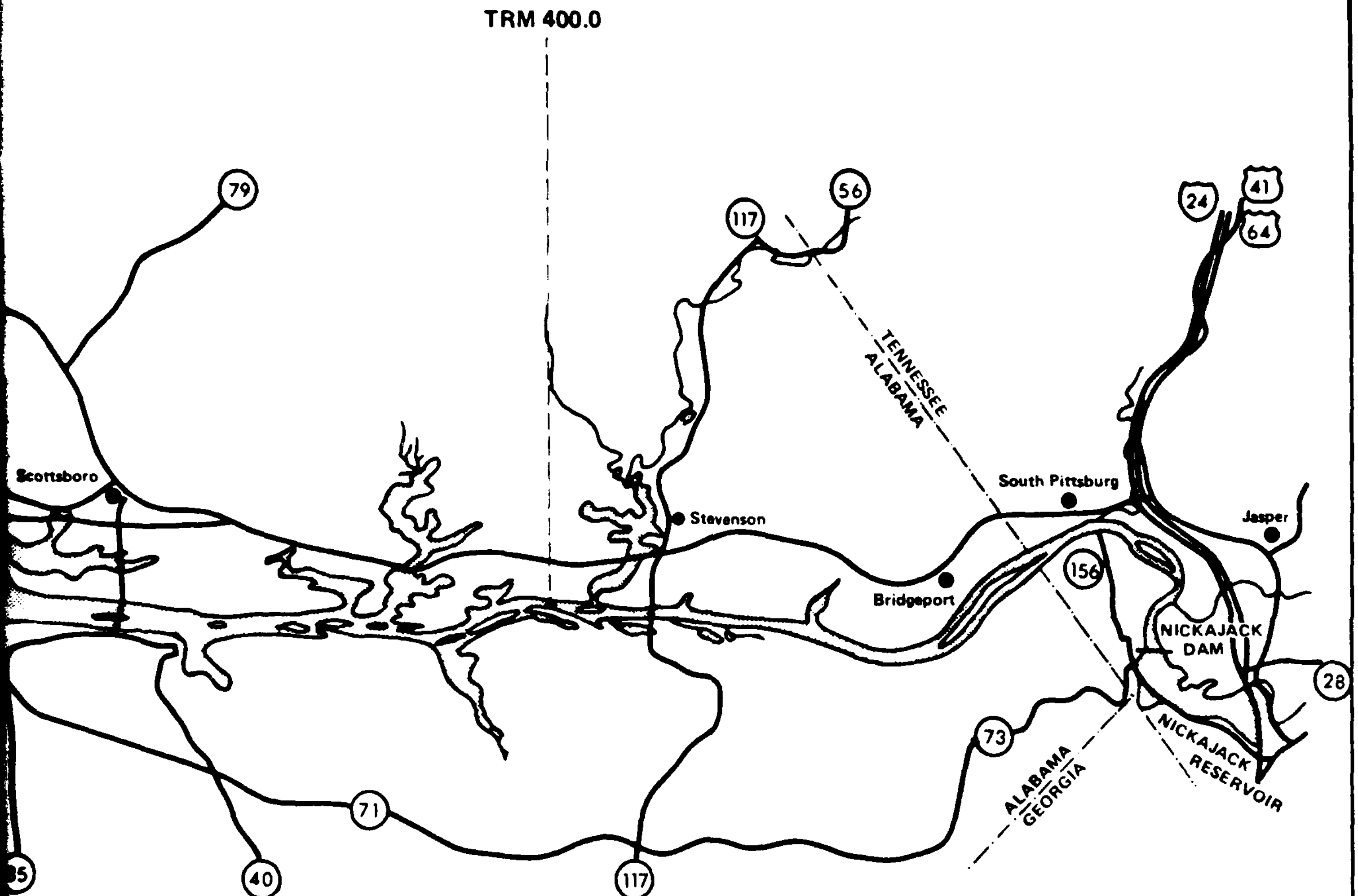


FIGURE 3. Tennessee River, Wilson and Wheeler Reservoirs

SOURCE WATER AND AIR RESEARCH, INC., 1980



ENNESSEE RIVER
ERSVILLE RESERVOIR

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Engineering and Environmental Study of DDT Contamination of Huntsville Spring Branch, Indian Creek, and Adjacent Lands and Waters, Wheeler Reservoir, Alabama

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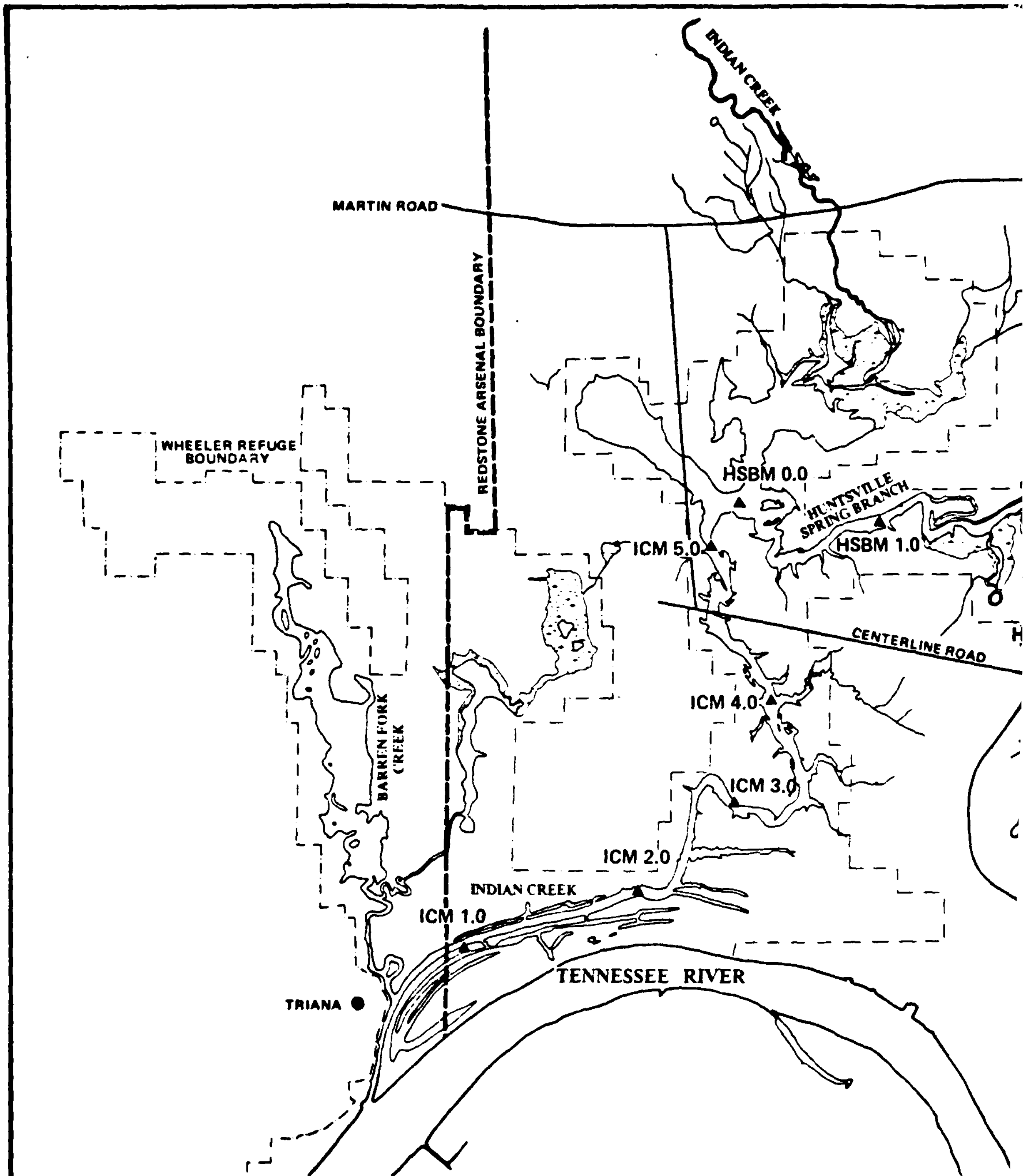
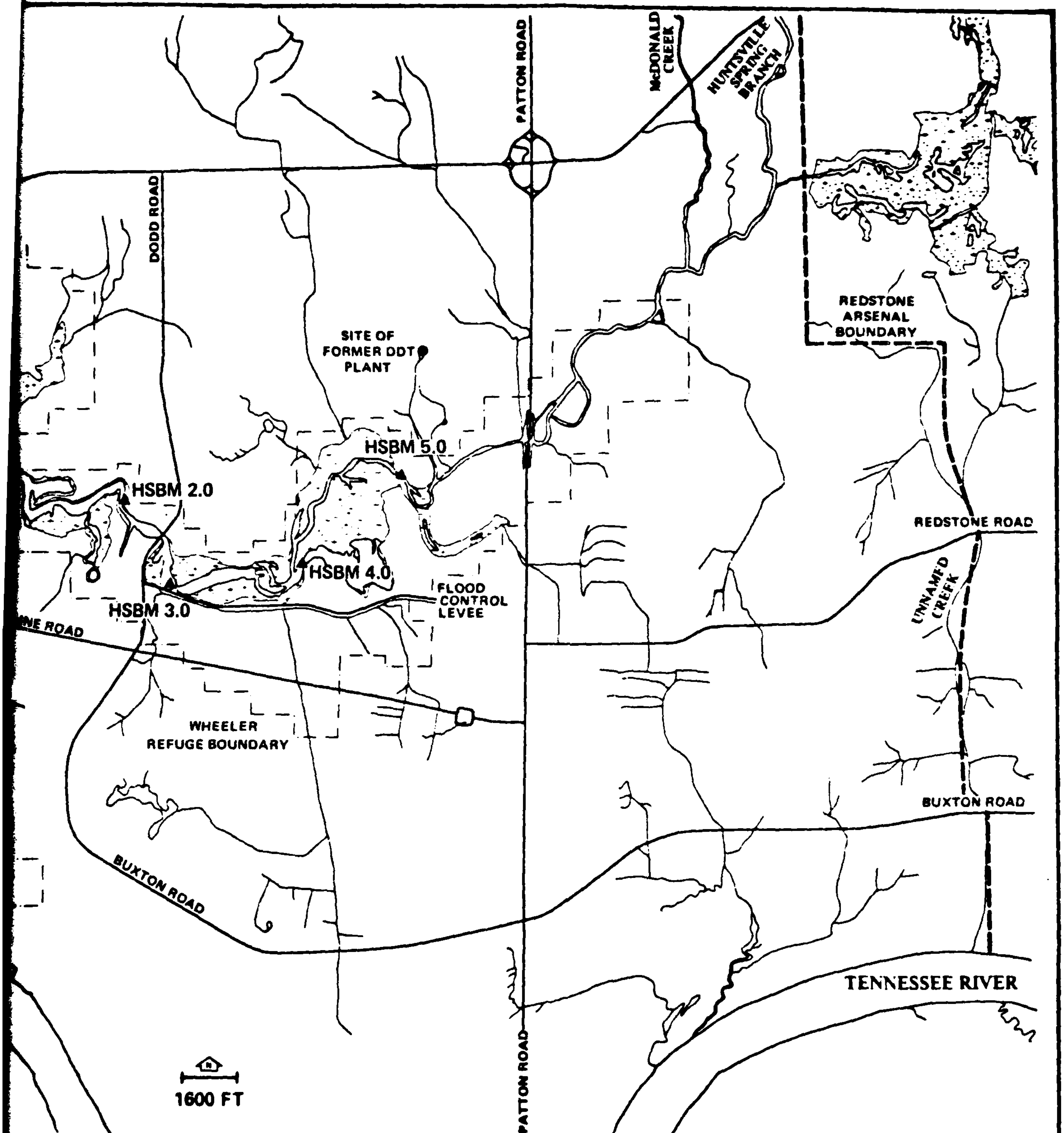


FIGURE 4. General Site Map - Huntsville Spring Branch, Indian Creek, and Vicinity

SOURCE: WATER AND AIR RESEARCH, INC., 1980



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Engineering and Environmental Study of DDT Contamination of Huntsville Spring Branch, Indian Creek, and Adjacent Lands and Waters, Wheeler Reservoir, Alabama

production rates or waste generation. The plant capacity was approximately 25 million pounds per year. In 1954 Olin Mathieson Chemical Company became the lessee and continued DDT manufacture. Records do show a production rate of 2.25 million pounds per month for all or some part of 1969. Increasingly stringent effluent standards (20 parts per trillion) were a factor leading to the decision to discontinue DDT production in June, 1970.

2.2 WASTE TREATMENT HISTORY

No records were found indicating any type of wastewater treatment prior to 1965. In that year an effluent standard of 10 ug/l (parts per billion) was established by federal officials and a settling basin or tank was installed. It was reported that the basin frequently filled to overflowing with solids. In 1967 additional settling capacity was added. A new discharge ditch was constructed parallel to the old ditch, which was treated with lime and ferrous sulfate and filled in. In February 1970 carbon filtration was added. In 1970 the Federal Water Quality Administration lowered the effluent limit to 0.020 ug/l DDTR. Production was terminated by June 1970. Two other pesticides were later manufactured at the site; trichloroacetonitrile (TCAN) for less than a month and methoxychlor for about six months. The plant was demolished in early 1972.

2.3 RESTORATION WORK ON REDSTONE ARSENAL

Extensive restoration of the manufacturing site has been carried out. Initially, upstream drainage was diverted around the site. Runoff from the site was routed to the waste drainage ditch. Two retention dams were constructed in the ditch. A water filtration/carbon adsorption unit has been installed to treat water in this ditch. Surface soil at the old plant site was removed and buried in a State approved landfill located on Redstone. Excavation and landfilling of the contaminated sediments in the old ditch has been accomplished and stabilization of other DDTR disposal sites and installation and operation of a subsurface water monitoring system is being carried out. For purposes of the subject study, it was assumed that no further contamination of HSB would result from remaining DDTR on Redstone Arsenal.

2.4 HISTORICAL ENVIRONMENTAL CONTAMINATION

2.4.1 Water and Sediment

No records were found of environmental monitoring prior to 1963. At that time the U.S. Public Health Service sampled water and sediment in Huntsville Spring Branch, Indian Creek, and the Tennessee River. Elevated DDTR concentrations were observed particularly in Huntsville Spring Branch and Indian Creek. Comparison of sediment DDTR concentrations reported through the years shows no significant variation with time. Indian Creek values are roughly in the 10-50 ug/g (parts per million) range, Huntsville Spring Branch from Mile 0 to 2.4 in the 50-3,000 ug/g range, and Huntsville Spring Branch from Mile 2.4 to 5.4 in

the 100-25,000 ug/g range. The wide variation in the latter reach results in part from the unequal distribution of DDTR across the wide floodplain that exists there. So called "hot spots" exist in the channel and overbank in this reach which may or may not have been sampled in any particular survey. Overall, the existing historical data do not show any significant change in sediment concentrations in Indian Creek and Huntsville Spring Branch from 1963 to 1979.

2.4.2 Fish and Wildlife

The first testing for DDTR in biota appears to have occurred in 1964. Wildlife collected near Huntsville Spring Branch included crows, swamp and cottontail rabbits, opossum, and gray fox. All species except the rabbits had average DDTR concentrations over 10 ppm in muscle tissue. One crow had 119 ppm DDTR.

As early as 1955, bird population estimates for Wheeler Wildlife Refuge showed a decline in Double-crested Cormorant populations. Other species, particularly raptorial birds, showed declines in the 1960's. DDTR may have been a factor in some of these declines but there is not sufficient data to establish such a relationship. Even if DDTR were a factor, nationwide or even regionwide agricultural usage may have been more important than the DDTR in HSB and IC.

The first reported fish survey data are from 1970. At that time white bass and channel catfish in Wheeler Reservoir had fillet DDTR concentrations up to 8.5 and 22.2 ppm respectively. In 1971, a statewide survey reported elevated levels of DDTR in fish from the Tennessee River. Analyses were made in the 1975-77 period on dressed fish from markets in the area. Most fish had DDTR levels below the 5.0 ppm FDA limit but one catfish had 115 ppm. In 1977, three surveys were made in the area. Whole body analyses were performed and many fish from the HSB-IC area had concentrations over 100 ppm. Similar results on other whole body analyses were obtained on fish sampled between 1977 and 1979. In 1977 and 1978 analyses performed on fillet samples showed high DDTR concentrations with several samples over 100 ppm. Consistently, the higher concentrations were found in the HSB-IC area and the TR within 10 miles of the IC confluence.

3.0 PRESENT SITUATION

3.1 DISTRIBUTION OF DDTR

3.1.1 Sediments

Huntsville Spring Branch and Indian Creek--The mass distribution of DDTR in IC and HSB is shown in Table I. About 96 percent of the DDTR is located upstream of Dodd Road in HSB. Another 3 percent is in HSB between Dodd Road and IC. About 1 percent of the total is in IC.

Table 1. Distribution of DDTR in Sediments

Location	Depth	Tons as DDT: DDT	DDD	DDE	DDTR
Upstream of Dodd Road	0-6"	250	80.5	44.0	375
	6-12"	182	86.7	42.8	311
	12-24"	21.8	49.1	15.1	86.0
	>24"	26.5	4.5	1.0	32.0
TOTAL		480	221	103	804
Dodd Road to Mouth of Huntsville Spring Branch	0-6"	7.9	7.1	2.5	17.5
	6-12"	1.9	2.9	1.4	6.2
	12-24"	0.26	0.32	0.22	0.79
	>24"	0.01	0.01	0.01	0.03
TOTAL		10.1	10.4	4.0	24.5
Indian Creek	0-6"	1.4	1.9	1.3	4.5
	6-12"	0.53	0.77	0.77	2.1
	12-24"	0.44	0.78	0.65	1.9
	>24"	0.01	0.01	0.01	0.04
TOTAL		2.4	3.5	2.7	8.5
OVERALL TOTAL		493	235	110	837

Note: All results have been rounded to no more than three significant figures.

About 47 percent of the DDTR is contained in the top six inches of sediment and about 86 percent is in the top 12 inches.

The DDTR areal distribution in pounds per acre for the most contaminated area of HSB is shown in Figure 5. The most contamination exists in the channel and overbank upstream of Dodd Road (HSBM 2.4).

DDTR concentrations in stream bottom and overbank samples are shown in Table 2.

Tennessee River (Excluding Huntsville Spring Branch and Indian Creek)--Detectable quantities of DDTR were found in all (9 total) surface sediment samples in the Tennessee River from Mile 300 in Wheeler Reservoir to Mile 260 in Wilson Reservoir. Hard or rock bottom conditions precluded sediment sampling at some locations. The average concentration actually detected was 0.08 ppm with a range of 0.05 to 0.10 ppm. If isomers not detected were considered at stated detection limits, the average would increase to 0.18 ppm with a range of 0.16 to 0.19 ppm.

No DDTR was detected in four samples from TRM 320.8 to 375.

Detectable concentrations of DDTR were found in three of seven tributaries to Wheeler Reservoir. Two, Limestone Creek and Spring Creek, are located below Indian Creek and the other, Paint Rock River, above.

Total estimated DDTR amounts in sediments, excluding HSB-IC, is as follows:

	Tons
Tennessee River Mile 275-300	2.1 - 4.2
Wilson Reservoir	0.68 - 1.6
Other TR Tributaries	0.13 - 0.36
Total	2.9 - 6.2

3.1.2 Water

In the Tennessee River samples taken in July-August 1979 were below analytical detection limits. In December 1979 low but detectable (generally $<$ 1ug/l) quantities were found, primarily in water samples taken near the bottom. Sampling during storms in the IC-HSB system showed DDTR concentrations up to 17.8 ug/l, most of which was associated with the suspended solids. Overall, the amount of DDTR that can be expected in the water column in Wheeler Reservoir at any one time is estimated to be less than 0.3 tons to not over 1 ton.

3.1.3 Biota

Estimates were made of the total DDTR contained in the following groups: macroinvertebrates, birds, fish and other vertebrates. The area included

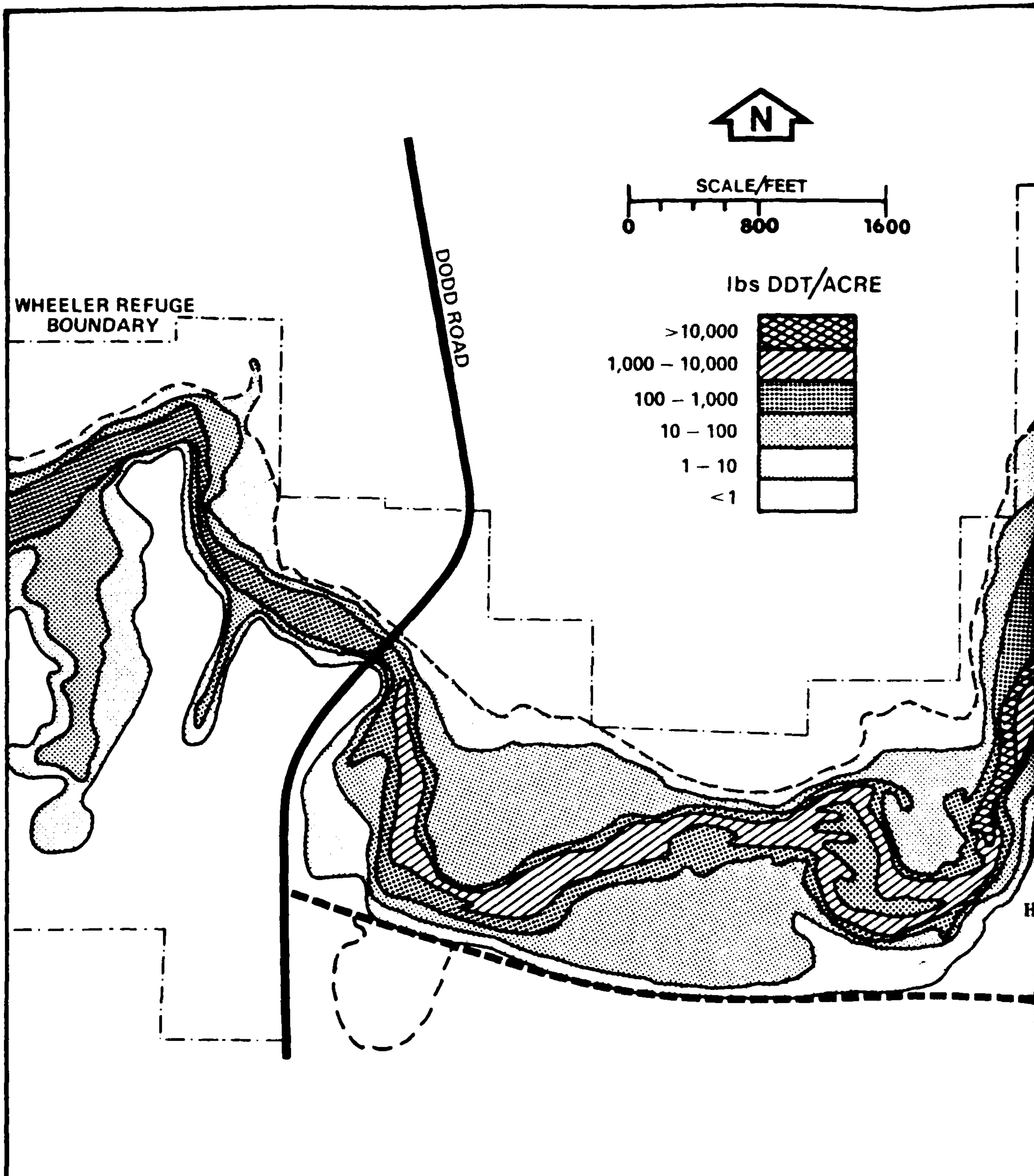
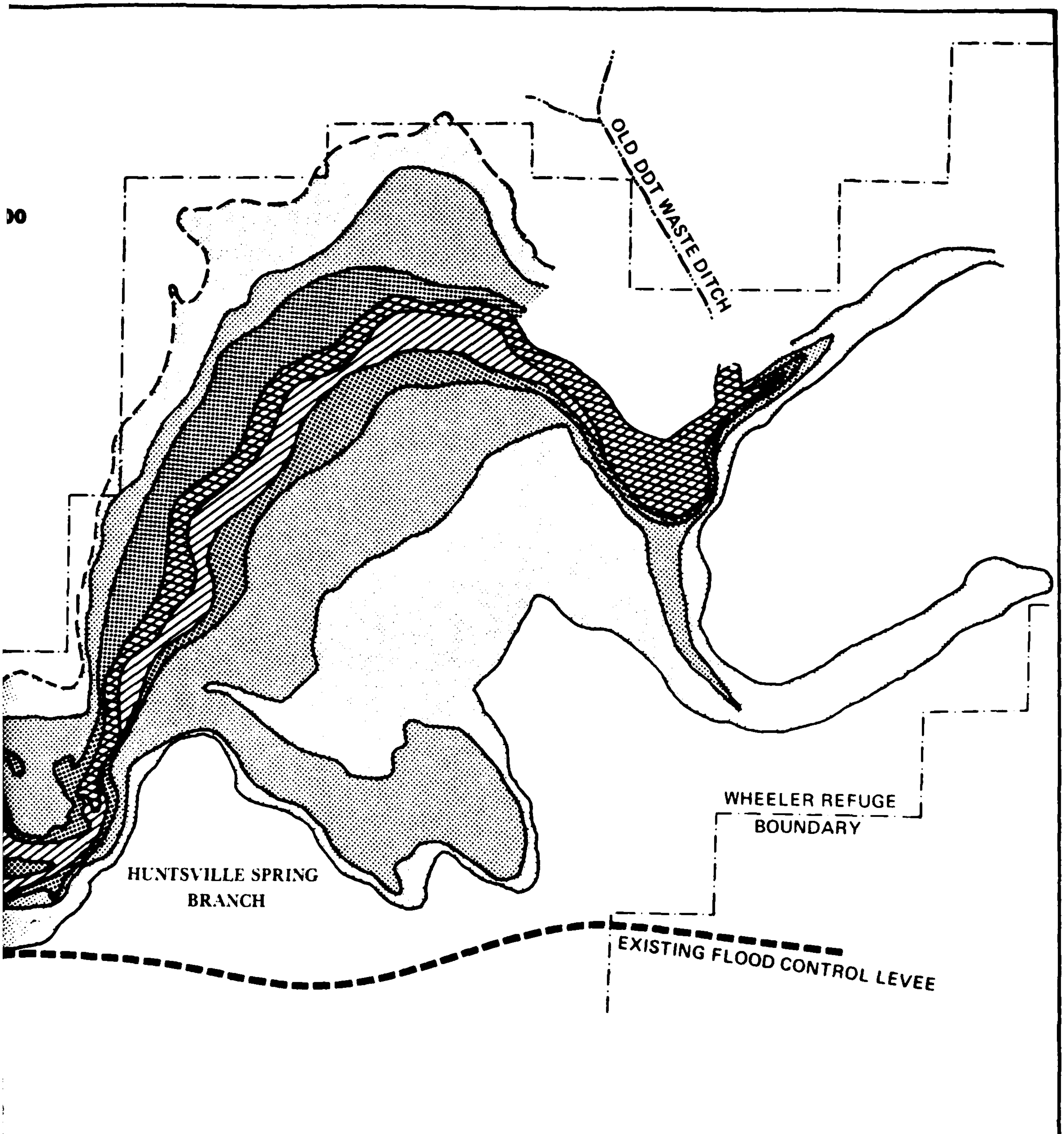


FIGURE 5. Extent of DDT Residue Contamination of Surface Sediments in Huntsville Spring Branch Between Mile 1.5 and 5.6

SOURCE: WATER AND AIR RESEARCH, INC., 1980



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1 2

Table 2. Summary of Stream Bottom and Overbank Sediment DDTR Concentrations in Indian Creek, Barren Fork Creek and Huntsville Spring Branch, August 1979.

Location	Depth Horizon	No. Samples	Sediment DDTR Concentration[1] (ppm as DDT) Mean	Range
ICM 0-5	0-6"	18	17.8	<1.01 - 30.8
	6-12"	10	8.88	4.65 - 15.2
	12-24"	10	5.83	<0.81 - 15.8
	>24"	3	0.61	<0.16 - 1.51
	Overall		8.75	<0.16 - 30.8
HSBM 0-2.4	0-6"	15	97.8	<2.26 - 403
	6-12"	14	9.99	<0.13 - 42.1
	12-24"	8	3.30	<0.37 - 9.77
	>24"	2	0.72	<0.66 - 0.78
	Overall		38.1	<0.13 - 403
HSBM 2.4-5.4	0-6"	54	1,360	<0.86 - 14,700
	6-12"	45	2,160	<0.09 - 30,200
	12-24"	28	299	<0.19 - 2,730
	>24"	3	1,820	<0.38 - 12,100
	Overall		1,540	<0.09 - 30,200
HSBM >5.4	0-6"	3	0.63	0.63
	6-24"	3	0.48	0.48
	12-24"	3	0.30	0.30
	Overall		0.47	0.30 - 0.63
Floodplain[2]	0-6"	11	0.95	<0.13 - 2,420
BFC	Overall		<0.94	<0.94

NOTES:

[1] All less than values assumed equal to stated value.

[2] Mean excludes station HSB FP 1, floodplain station near mouth of "Old Waste Ditch", and includes "Floodplain" stations in Indian Creek.

for fish and macroinvertebrates was Wheeler Reservoir. For birds and other vertebrates, Wheeler National Wildlife Refuge was considered. Because precise data are not available for either total populations or average DDTR concentrations, these data should be considered only as best estimates. The purpose of this data is to show the total amount of DDTR in biota for comparison with amounts in other substrates. The biological significance of DDTR in biota is discussed in other sections of this report.

Organism	Total DDTR Pounds	Total DDTR Tons
Macroinvertebrates	14	0.007
Fish	34 to 340	0.017 to 0.17
Birds	2	0.001
Other Vertebrates	6	0.003
Total	56 to 362	0.03 to 0.18

3.1.4 Overall Distribution of DDTR

Overall, the DDTR is contained predominately in sediments as shown below.

Substrate	Location	Tons DDTR	% of Total
Sediments	HSB-IC	837	99.4
Sediments	Wilson and Wheeler excluding HSB-IC	2.9 - 6.2	0.3 - 0.7
Water		<0.3 - 1.	<0.04 - 0.1
Biota		0.03 - 0.18	<0.01 - 0.02
Total		840 - 844	100

3.2 CURRENT CONTAMINATION LEVELS

3.2.1 Plankton

No accurate analysis of DDTR in plankton could be made as it was not possible to separate the plankton from inorganic suspended solids which also contained high concentrations of DDTR.

3.2.2 Macroinvertebrates

A strong relationship between DDTR concentration in macroinvertebrates and location relative to contaminated sediments is evident. In the Tennessee River macroinvertebrate DDTR concentration ranged from 0.02 to 0.50, in Indian Creek from 24 to 355, and in Huntsville Spring Branch from 2.5 to 2,710 ppm.

3.2.3 Fish

1979 Survey Results--Fish were sampled in Wheeler Reservoir on three occasions in 1979. The results for channel catfish, shown in Table 3, indicate a marked downward trend during the year. This may be due to

1) actual decreases in average DDTR concentrations,
2) seasonal cycles in DDTR concentration,
3) extensive migration of contaminated fish, and/or
4) differences in analytical procedures used or analytical inaccuracy

Examination of quality control results for the May and July-September data indicate that, compared to the EPA, Athens, Georgia laboratory, the May results were biased high and the July-September results were biased

low. If the EPA laboratory is assumed to have been a constant factor through both studies, about 75 percent of the difference between the May and July-October results can be attributed to laboratory bias. However, the even larger difference between the April and July-October results is unexplained. Slight variations in analytical procedure may have been responsible for some of the differences.

The results of the July-October 1979 sampling for the four most frequently sampled species are shown in Table 4. Channel catfish appear to be the most susceptible food fish of those tested to DDTR contamination. Bluegill and white crappie (results not presented in Table 4) showed concentrations above 1 ppm only in Indian Creek. The results for largemouth bass show contaminated conditions upstream of Indian Creek in the Tennessee River. This may be due to migration of contaminated fish.

For three species of fish at three locations both whole body and fillet samples were analyzed. The DDTR in the whole body samples was from 2 to 35 times higher than in the fillet samples.

1980 Survey Results--An additional fish survey was made in June-July 1980 and the results are summarized in Table 5. Channel catfish, smallmouth buffalo, and largemouth bass were sampled. Quality control results showed no laboratory bias as compared to EPA. Generally the contamination levels found were near those found in the May 1979 survey. At all locations from TRM 275 to 340 composite channel catfish samples had DDTR levels greater than 5 ppm. For unknown reasons, samples from Flint Creek mile 5 had elevated DDTR values.

In the TR below IC 17 of 30 individual smallmouth buffalo samples equalled or exceeded 5 ppm. Six individual fish sampled above IC had DDTR levels less than 5 ppm.

Of 12 largemouth bass sampled at TRM 285 and 345, only one had DDTR above 5 ppm.

Three of the four surveys in 1979-80 showed significant contamination of channel catfish in Wheeler Reservoir particularly in the IC area.

Table 3. Comparison of DDTR Concentrations in Channel Catfish Fillets in 1979

Location	April	May	July-Oct.
TRM-270	---	2.6	1.3
TRM-275	---	9.3	1.8
TRM-280	---	10.	0.7
TRM-285	---	6.7	---
TRM-290	---	9.	2.0
TRM-295	---	3.5	1.9
TRM-300	---	16.	12.5
TRM-305		65.	12.8
TRM-310		31.	1.2
TRM-315	133	16.	9.1
TRM-320		70.	9.6
TRM-325		28.[1]	0.3
TRM-330	390	71.	0.35
TRM-335		4.6[2]	0.35
TRM-340	---	17.[1]	1.2
TRM-345	---	1.9[2]	1.2
TRM-350	---	2.9[3]	---
TRM-355	---	1.7	---

Concentrations in ug/g

TRM 270 in Wilson Reservoir
TRM 350-355 in Guntersville Reservoir
All other sites in Wheeler Reservoir

Unless otherwise noted all samples are six fish composites.

1 Five fish composite
2 Four fish composite
3 Three fish composite

Source: April and May data are from Tennessee Valley Authority. July - Sept. data were collected as part of the current study (see Appendix V - TVA Task 1) TVA, 1979b.

Table 4. Summary of DDTR Results of July-October 1979 Fish Survey

Location	Channel Catfish	Smallmouth Buffalo	Largemouth Bass	Bluegill
CCM 2	56(3.3-139)	0.15	0.35[2]	0.25
ERM 5	1.2(0.4-2.3)	1.35	0.05	0.05
ERM 10	0.55	1.1	0.05	0.05
ERM 15	0.4	0.25	0.05	0.05
FCM 5	3.75(0.15-19.1)	0.25	0.15	0.2
FRM 1	0.5(0.1-2.6)	---	0.05	0.05
ICM 2	186(15.5-627)	16.2(2.2-44)	1.4[2]	4.2(2.1-6.6)
LCM 3	4.3	5.4(0.25-1.1)	0.15[2]	0.15
PRRM 1	0.2(0.2-2.6)	0.4	0.05	0.05
SCM 1	1.95	1.1	0.05	0.05
TRM 260	0.6	---	0.1	0.05
TRM 265	---	---	0.05	0.1
TRM 270	1.3	1.6	0.15	0.2
TRM 275	1.8(1.2-10.1)	3.9	0.05[2]	0.15
TRM 280	0.7	2.8	0.05[2]	0.1
TRM 285	---	0.7	0.25	0.05
TRM 290	2.0(0.45-2.2)	5.1(0.25-4.5)	0.15	0.05
TRM 295	1.9	2.1	0.10	0.05
TRM 300	12.5(1.4-46.3)	0.9	0.4	0.05[2]
TRM 305	12.8(1.3-21.0)	0.3	0.15[2]	0.05[2]
TRM 310	1.2	3.2	0.15[2]	0.2
TRM 315	[4]9.1(3.0-40.0)	2.75	9.2[2](0.5-3.1)[1]	0.25
TRM 320	9.6(0.8-22.0)	1.2	2.8	0.7
TRM 325	0.3	1.3	6.0	0.15
TRM 330	0.35	0.9	2.3(0.55-16.1)	0.1
TRM 335	0.35	0.6	7.3(1.9-11.9)	0.05
TRM 340	1.2	0.7	0.8[3]	0.1
TRM 345	1.2(0.8-3.7)	0.5	1.5	0.05
TRM 350	---	---	0.25	0.05
TRM 375	0.15	0.5	0.05	0.05
TRM 400	---	0.6	0.05	0.05

Notes: First number is DDTR concentration in a six fish composite. Concentration in ug/g
Numbers in parenthesis are range of results from individual fish analyses.
Fillet samples for all except gizzard shad.
TRM 260-270 in Wilson Reservoir
TRM 350-400 in Guntersville Reservoir
All other sites in Wheeler Reservoir

[1]Only two individuals analyzed.
[2]Results may be low - run on 12 December. See Quality Assurance Document.
[3]EPA got 9.4 for this sample.
[4]EPA got 25.4 for this sample.

Table 5. Summary of DDTR Results of June-July 1980 Fish Survey

Location	Species	Composite Sample	Individual Fish Samples Average	Individual Fish Samples Range
TRM 275	CC	9.3	11	4.5-25
TRM 280	CC	8.5	8.0	5.5-13
TRM 285	CC	15	9.5	2.8-19
TRM 290	CC	15	13	3.5-22
TRM 295	CC	15	14	4.7-31
TRM 300	CC	9.0	11	3.0-18
TRM 305	CC	10	14	9.7-22
TRM 310	CC	9.2	9.2	3.8-17
TRM 315	CC	5.4	7.6	3.3-13
TRM 320	CC	120	120	13-360
TRM 325	CC	100	190	0.74-1100
TRM 330	CC	34	32	2-140
TRM 340	CC	25	33	1.5-180
FCM 5	CC	50	45	10-150
LCM 3	CC	14	13	2-28
SCM 1	CC	5.8	5.0	2.6-9.1
TRM 280	SMB	6.4	3.9	2.3-6.8
TRM 290	SMB	12	10	3.4-21
TRM 300	SMB	6.3	5.0	1.3-10
TRM 310	SMB	4.3	4.0	1.4-6.1
TRM 320	SMB	25	24	0.43-48
TRM 330&340	SMB	0.89	0.95	0.25-2.5
TRM 285	LMB	0.38	0.36	0.11-0.80
TRM 345	LMB	2.1	2.4	0.35-7.4

Concentrations in ug/g

CC=Channel Catfish, SMB=Smallmouth Buffalo, LMB=Largemouth Bass.

Six individual fish were taken at each sampling location. All analyses were in fillet samples.

Smallmouth buffalo appear to be contaminated, particularly at and downstream of IC. Largemouth bass have lesser overall contamination but some individual fish had relatively high DDTR levels.

Method of Contamination--The source of contaminated fish in the Tennessee River is of significant concern. Several possibilities exist. The river could contain sufficient DDTR residues from IC-HSB or from other sources to contaminate fish. The contamination could result from fish becoming contaminated in IC-HSB and migrating out into the river.

Sediment analyses clearly show the IC-HSB system as being a major source of DDTR. Further, it has been shown that at least some DDTR is being transported out of the IC-HSB system to the TR. Sediment and water analyses for the TR and tributaries indicate no other significant source of DDTR.

Except for the unexplained high levels in channel catfish at Flint Creek Mile 5, the pattern of contamiantion for individual fish in the June-July 1980 survey also suggests HSB-IC as the primary source of DDTR. Downstream of IC more than 80 percent of the catfish had DDTR levels above 5 ppm. It seems likely that such a consistent pattern of contamiantion would result from in situ conditions rather than migration. Above IC individual fish concentration were more variable and suggested migration as a likely source of upstream contamination.

3.2.4 Birds

Current data for DDTR in Green Herons and Wood Ducks from TRM 271 to 402 are reported in this study. Birds from the IC-HSB area had almost an order of magnitude higher DDTR concentration than birds from other parts of the study area. Both Crows and Mallard ducks collected in February 1979 had geometric mean DDTR concentrations of 4.0 ppm in muscle tissue. Mallard wing analyses for the 1978-79 hunting season showed order of magnitude higher DDTR levels for birds from Limestone and Madison Counties as compared to other Alabama counties surveyed. The Arsenal is in Madison County and Limestone is the next county west.

3.2.5 Mammals

DDTR levels in shrews were 52 ppm in HSB and no higher than 7.7 ppm in five other areas. Muskrats from HSB had 0.26 ppm DDTR and less than half that in five other areas. Cottontail and swamp rabbits from the Arsenal contained mean concentrations of 0.27 and 0.25 ppm DDTR.

3.2.6 Reptiles

Snapping turtles and water snakes from HSB had DDTR concentrations of 0.45 and 1.8 ppm respectively. These were the highest values reported in samples from this area.

3.2.7 Vascular Plants

Buttonbush samples from HSB had a DDTR concentration of 0.065 ppm compared to 0.005 ppm at TRM 359 upstream. Duckweed from the most contaminated stretch of HSB had concentrations as high as 5.6 ppm. Hibiscus was found to contain 0.786 ppm DDTR in HSB compared to 0.004 ppm at TRM 359.

3.3 ENVIRONMENTAL TRANSPORT OF DDTR

Of particular concern in evaluating the current situation and predicting future conditions is the stability of the DDTR now in the system. Is the contamination spreading and if so, how? Or is the DDTR degrading and/or becoming isolated from the rest of the environment? Two means of transport were considered, physical and biological.

3.3.1 Physical Transport of DDTR

Because the vast majority of DDTR is found in the sediments, processes which would tend to move sediments were of particular interest. Thus sediment transport, particularly during high flow storm events, was expected to be important. Sampling was carried out during a number of storm events at four locations in the HSB-IC system to evaluate DDTR transport. Measurements, including rainfall, stage, discharge, suspended solids, volatile suspended solids as well as suspended (i.e., passing a 63u sieve and retained on a $\sim 1\mu$ glass fiber filter) and dissolved/suspended (i.e, passing a $\sim 1\mu$ glass fiber filter) DDTR concentrations, were made a number of times during each storm runoff event. Usable data were obtained form three storm events.

In order to estimate DDTR transport rates, multiple regression models were developed relating suspended DDTR transport rates to sampling locations, discharge, type of runoff event (i.e., headwater or tailwter) and the transport rate of the corresponding suspended solids loading rate (i.e., $<63\mu$ and $>1\mu$) and relating dissolved/suspended DDTR transport rates to sampling locations, discharge and the volatile suspended solids loading rate (i.e., $<63\mu$ and $>1\mu$). Seasonal and annual flow duration relationships were developed at each sampling location, the seasons winter (November-April) and summer (May-October) being defined with respect to Wheeler Reservoir operational procedures. Suspended and volatile suspended solids loading rates were related to sampling location and discharge utilizing multiple regression techniques. The frequency with which tailwater runoff events occurred in the lower reaches of HSB-IC were estimated from an examination of the regional topography and seasonal stage duration relationships developed for the Tennessee River at Whitesburg, Alabama. The combination of these data yielded estimates of the seasonal and annual DDTR transport rates within and out of the IC-HSB system. Predicted annual DDTR transport rates and 95 percent confidence limits are as follows:

Location	DDTR Loading (tons/yr as DDT)	95% Confidence Limits (tons/yr as DDT)
Upstream of Old DDT Waste Ditch:		
HSBM 5.9	0.01	0.006 to 0.05
Downstream of Old DDT Waste Ditch:		
HSBM 2.4	0.62	0.25 to 1.6
ICM 4.6	0.99	0.44 to 2.2
ICM 0.9	0.64	0.31 to 1.3

As these figures indicate, DDTR is being scoured upstream of Dodd Road and is being transported downstream to the Tennessee River. Over two thirds of the DDTR transport out of the IC-HSB system occurs during the winter months (Nov-April). The DDTR load to the Tennessee River is about equally divided between the suspended fraction, associated with silt and medium and coarse clay sized materials, and the dissolved/suspended fraction, either dissolved or associated with fine clays and colloidal material. It snould be noted, that at the rate at whcih the DDTR contamination in the IC-HSB system is being transported to the Tennessee River by fluvial transport processes, i.e., 0.04 to 0.2 percent per year, it will take centuries to flush the system.

3.3.2 Biological Transport of DDTR

Compared to sediment amounts, the very low total amounts of DDTR in the biota make biological transport an unimportant factor in the overall dispersion of DDTR. However, food chain links can be an important mode of contamination for biota.

4.0 ALTERNATIVES FOR MITIGATION OF DDT CONTAMINATION IN HUNTSVILLE SPRING BRANCH AND INDIAN CREEK

4.1 INTRODUCTION

Six alternatives are presented for mitigation of DDTR contamination in HSB and IC. They are:

A) Natural Restoration,
B) Dredging and Disposal,
C) Out-of-Basin Diversion and Removal of Contaminated Sediments,
D) Out-of-Basin Diversion and Containment of Contaminated Sediments,
E) Within-Basin Diversion and Removal of Contaminated Sediments, and
F) Within-Basin Diversion and Containment of Contaminated Sediments.

A number of other alternatives, including in-place stabilization or detoxification and impoundment structures, were considered but proved not to be feasible.

These alternatives do not deal with DDTR contamination in the TR. Concentrations of DDTR in the TR sediments are approximately two orders of magnitude below those in IC, being on the order of non-detectable to

These alternatives do not deal with DDTR contamination in the TR. Concentrations of DDTR in the TR sediments are approximately two orders of magnitude below those in IC, being on the order of non-detectable to 0.2 ppm compared to typical concentrations of 10 to 30 ppm in IC sediments.

Because of these low concentrations and the large area over which low-level contamination is dispersed in the TR, mitigation alternatives there appear to be economically infeasible. The relatively high (10 to 30 ppm) concentrations of DDTR in IC channel sediments warrant consideration of mitigation alternatives in IC upstream to the HSB confluence. It is apparent that this level of contamination is a major source of DDTR in fish inhabiting IC and the TR. Due to the flows encountered in IC and the infeasibility of containment alternatives there, the only practical means of dealing with this contamination is by dredging the sediments. With the exception of the natural restoration alternative, all alternatives presented include the dredging of IC in addition to mitigating contamination in HSB.

Presentation of the alternatives will begin with a discussion of relevant properties of DDT and physical characteristics of the study area. These considerations are of paramount importance in assessing the effectiveness and environmental acceptability of the alternatives.

Alternatives B through F are centered around one or more of four major physical actions; dredging and disposal, an out-of-basin diversion of HSB, a within-basin diversion of HSB, and in-place containment of contaminated sediments. To avoid redundancy in discussing the alternatives, these four major actions will be discussed first on an individual basis, along with their respective impacts. Each complete alternative will be discussed in a later section and the major physical actions associated with it will be referenced to the earlier discussions. Separate sections appear for areawide environmental monitoring and legislation, regulations, and permitting associated with the alternatives. A summary comparison of alternatives is presented in the final section.

4.2 CHARACTERISTICS OF DDT-SEDIMENT ASSOCIATION

4.2.1 Introduction

The approach taken in this study is to design a technically feasible and environmentally sound course of action with respect to alternatives for removal, containment, and disposal of DDTR-contaminated sediments. The effectiveness of each alternative is dependent on the properties of DDTR and the sediments with which it is associated. The purpose of this section is to summarize those properties which form the basis of the removal, containment, and disposal alternatives presented.

4.2.2 DDT Mobility in Sediments

All DDTR isomers are extremely hydrophobic, their solubility in water being on the order of 1.2 ppb. Numerous researchers have reported the

strong tendency for DDT to adsorb on solid materials when in an aqueous medium, particularly to clay minerals, iron and manganese hydrated oxides, and organic material.

Leaching characteristics of DDTR in field disposal sites and laboratory columns have been well documented . In all cases, DDTR in leachate was at very low or non-detectable levels. Similar results are reported for DDTR in elutriate from DDTR-contaminated sediments and in water overlying DDTR-contaminated sediments. Elutriate DDTR levels in sediments from the highly contaminated areas of HSB, however, were significantly higher than those reported in the literature. Using experimentally derived relationships between mobility of various chemicals in soils and estimated soil parameters typical of the HSB-IC area, it was estimated that in order for DDTR to migrate one inch in the sediments, 1,427 inches of water must pass through the sediments.

4.2.3 Characteristics of Sediments in the Study Area

Sediments in cores taken from HSB and IC under Task IV are largely fine-grained, with an average of 78 percent of each sample passing the 63μ sieve. Volatile solids content of the sediment samples averaged 7.5 percent. The average *in situ* void ratio of submerged sediments was 1.45, corresponding to 38 percent water by weight. When dewatered to a 15 percent water content, the void ratio of the sediments would be decreased to 0.35.

Surface soils in the proposed borrow and disposal areas are silty clays with clayey subsoils. Typically 75 to 95 percent of these soils will pass the 63μ sieve. Surface soils are typically underlain by 10 to 30 feet of inorganic clays of varying plasticity.

4.2.4 Summary and Discussion

Due to its hydrophobic and high adsorptive properties, DDTR will be strongly associated with solid materials in an aqueous medium, particularly with clays and organic matter. DDTR-contaminated sediments in HSB and IC are predominantly clays, with approximately 7.5 percent volatile solids. The nature of these sediments indicates that DDTR will remain strongly adsorbed to them and will be transported only if the sediments are transported.

Alternatives involving dredging in flowing reaches of HSB and IC should be designed to minimize suspension of contaminated sediments into the water column. By controlling turbidity, downstream transport of DDTR during dredging will also be controlled.

The close association of DDTR with sediment particles is responsible for its nearly total inability to leach through soils or dredged material. With this in mind, it is evident that any containment or disposal method which will effectively contain the contaminated sediments will also effectively contain the DDTR. An important factor in developing the proposed alternatives is the predominance of clays in the study area. Contaminated sediments, soils underlying proposed disposal area, and soils to be used for dike construction and covering contaminated

sediments are largely clays or silty clays. The impermeability of the clays to the passage of water together with the strong affinity of DDTR for the clay particles indicates that migration of DDTR from a properly designed and constructed disposal or containment area will be negligible.

4.3 DREDGING AND DISPOSAL

4.3.1 Introduction

DDTR contamination in HSB and IC is closely associated with the sediments, as discussed in Section 4.2. Presently this DDTR is available to the immediate biosphere and is subject to further dispersal by hydraulic transport with the sediments during elevated flow conditions in HSB and IC. By physically removing the contaminated sediments and disposing of them in a manner designed to effectively isolate them, the long-term potential for bioavailability and further dispersal of DDTR in the environment would be effectively eliminated.

Areal Distribution of DDTR--The distribution of DDTR in HSB and IC is determined from the results of Task IV. Sediment cores were taken along 22 sampling transects in HSB and IC. Results of the core analyses indicate that DDTR contamination is almost entirely confined to the upper 2 feet of sediment. Table 5 illustrates the areal distribution of DDTR in HSB and IC. Reaches A, B and C are so designated because of their marked differences in total areal concentration of DDTR.

As indicated in Table 6, the majority of DDTR is contained in the channel sediments and in the area designated "critical overbank" adjacent to the channel between HSB Miles 3.8 and 4.7 (illustrated in Figure 6). Three dredging plans are designated as I, II, and III in Table 7 according to which reaches of HSB and IC are included, i.e., the level of contamination desired to be removed from the system. Contamination in the non-critical overbank of Reach A is typically 5-40 ppm DDTR, sufficient to warrant consideration of removing those sediments. Overbank areas in Reaches B and C and all adjacent ponded areas have DDTR concentrations less than 10 ppm and are out of the normal flow channels. Therefore, they will not be considered for dredging.

Approach for Implementation--Evaluation of existing equipment and conditions to be encountered at the site indicate that hydraulic dredging is the most feasible means of removing DDTR-contaminated sediment from flowing reaches of HSB and IC. A dredging operation would have to be preceded by snagging and clearing of trees, stumps, and other debris from the channel and its immediate banks. Dredged material would be pumped hydraulically to an on-site temporary disposal area designed to provide complete containment of the sediments and adequate treatment of the return water to HSB.

Following completion of the dredging operation, the dredged material would have to be dewatered before a permanent disposal plan could be implemented. Permanent disposal in the temporary disposal area appears to be the most feasible means of ultimate disposal. This basically involves sealing the area with an impermeable cover once the sediments

Table 6. Estimated Percentages of Total[1] DDTR Contained in Designated Hydrologic Areas of Huntsville Spring Branch and Indian Creek

Reach	Miles Included	Area Hydrologic Designation	Surface Area (sq yd)	Volume of Sediment Contained in 3-ft Depth Over Designated Area (cu yd)	Estimated Mass of DDTR in Designated Area (lbs)	Estimated % of Total DDTR in Designated Area	Typical Range of DDTR Concentration Encountered In Designated Area (ppm)
A	HSB Miles 5.6-2.4	Channel[2]	228,000	228,000	503,000	30.0	100-30,000
		Critical Overbank[3]	121,600	121,600	1,016,000	60.6	100-15,000
		Noncritical Overbank[4]	1,122,400	1,122,400	71,500	4.3	5-40
		Ponded[5]	293,000	293,000	7,100	0.4	1-5
B	HSB Miles 2.4-0.0	Channel	408,000	408,000	56,800	3.4	10-400
		Overbank	313,000	313,000	2,380	0.1	2-7
		Ponded	231,000	231,000	3,040	0.2	1-5
C	IC Miles 0.0-5.4	Channel	615,000	615,000	17,040	1.0	10-30
		Overbank	50,000	50,000	12	0.0	0-1
		Ponded	614,000	614,000	65	0.0	0-1

1. "Total" refers to the total estimated DDTR contained in HSB and IC.
2. Channel areas are designated as the inundated areas in the active flow regime at a pool elevation of approximately 555 feet. The channel is nearly bank-full at this elevation and is typified by well-defined banks and the absence of vegetation occurring in the overbank.
3. The immediate floodplain in HSB and IC inundated by high pool stage in the Wheeler Reservoir is designated as overbank. High DDTR levels in sediment cores from the critical overbank indicate that this area may contain the majority of DDTR in the HSB-IC system.
4. DDTR levels in the noncritical overbank are typically orders of magnitude less than those observed in the critical overbank, but still sufficiently high to warrant consideration of mitigation alternatives there.
5. Sloughs in HSB and IC which are permanently inundated but not subjected to normal channel flow are designated as ponded.

Table 7. Areal Dredging Plans for Dredging Huntsville Spring Branch and Indian Creek Channel Sediments

Dredging Plan	Reaches Included[1]	Miles Included	Volume of Sediment To Be Removed (cu. yd.)[2]	Estimated % of Total[3] DDTR Contained in Volume
I	A	HSB Mile 5.6-2.4	228,000 - hydraulic 121,600 - dragline	90.6
II	A,B	HSB Mile 5.6-0.0	636,000 - hydraulic 121,600 - dragline	94.0
III	A,B,C	HSB Mile 5.6- IC Mile 0.0	1,251,000 - hydraulic 121,600 - dragline	95.0
III plus Noncritical overbank	A,B,C	HSB Mile 5.6- IC Mile 0.0	1,251,000 - hydraulic 1,244,000 - dragline	99.3

1 Reaches designated in Table III-1 and shown in Figure III-7.

2 Figures based on removing 3 ft. of sediment from the channel

3 "Total" refers to the total estimated DDTR contained in HSB and IC

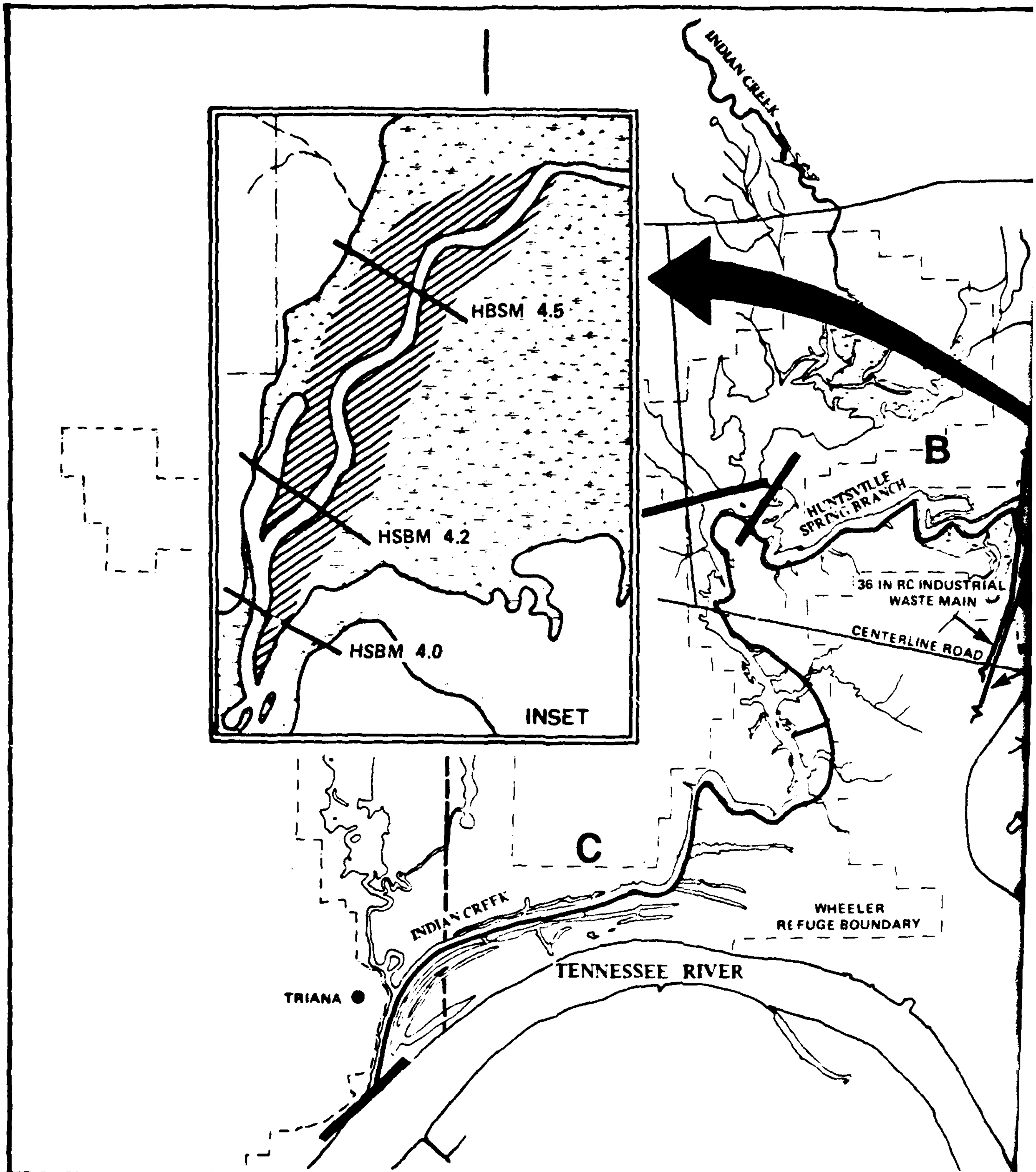
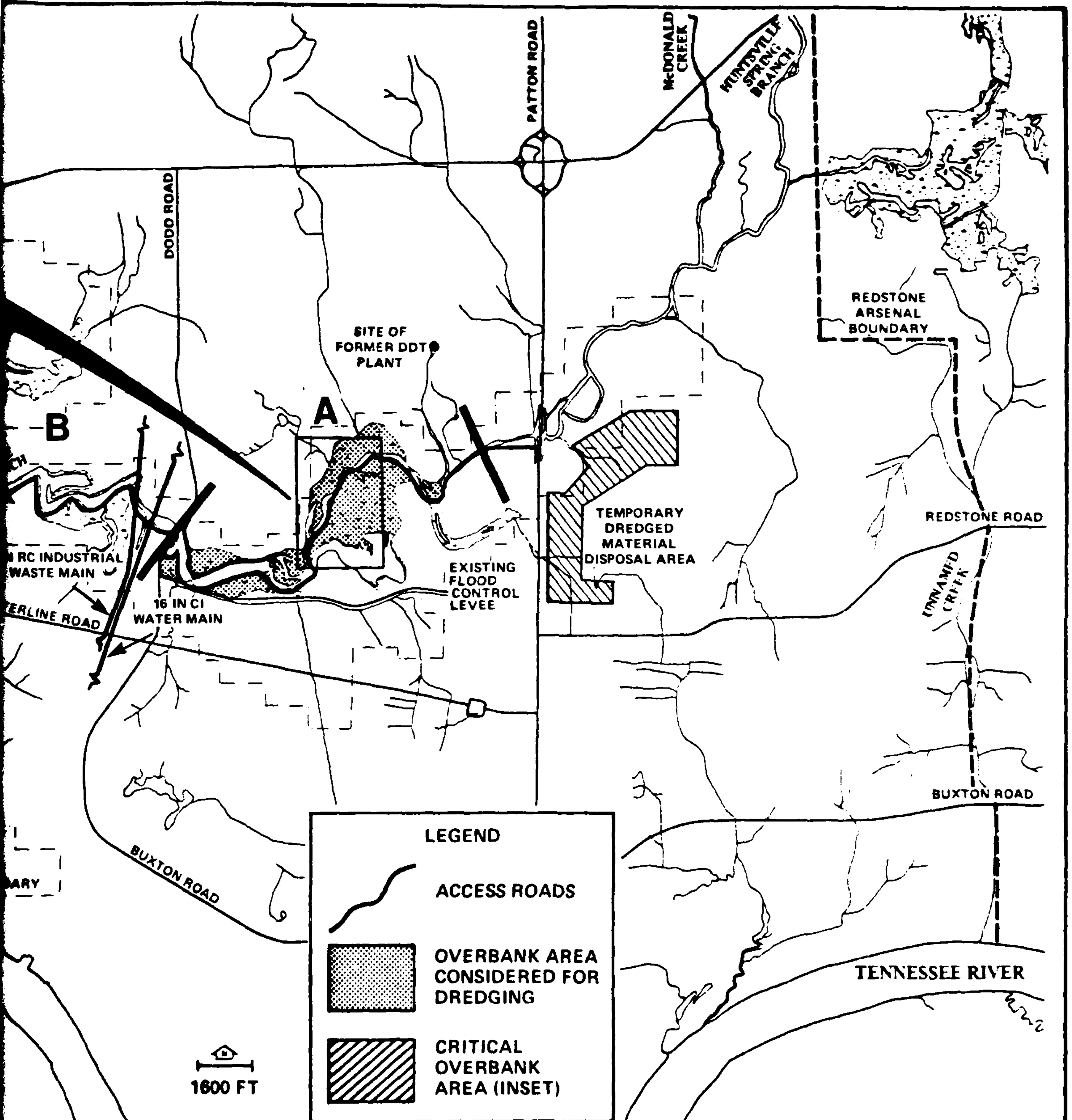


FIGURE 6. Areal Plan for Hydraulic Dredging in Huntsville Spring Branch and Indian Creek

SOURCE: WATER AND AIR RESEARCH, INC., 1980



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are dewatered. Factors favoring the environmental acceptability of this disposal technique are summarized in Section 4.2. Another option considered is to dispose of the dewatered material in an abandoned mine, prepared in such a manner as to effectively isolate the contaminated sediments.

4.3.2 Temporary Dredged Material Disposal Area (TDMDA)

Introduction--To implement a dredging alternative it will be necessary to site a temporary dredged material disposal area within reasonable pumping distance from the areas to be dredged. The disposal area must be carefully designed to assure containment of the contaminated sediments and to provide for adequate treatment of the overflow water. The location of the preliminary selected TDMDA is indicated in Figure 6.

Return Water Treatment System--Treatment of the return water will be necessary before it is discharged to HSB. The proposed treatment system is designed for complete solids removal with carbon adsorption to remove soluble DDTR. Disposal areas sized for Dredging Plans I and II will require 2 MGD capacity and that sized for Dredging Plan III will require 3 MGD.

Dewatering Dredged Material--Dewatering of the dredged material will be necessary before an ultimate disposal option can be carried out, be it on-site application of a stable impermeable cover, or transportation of the material to off-site mine disposal.

A series of studies conducted by the U.S. Army Engineer Waterways Experiment Station under the Dredged Material Research Program concluded that natural evaporative drying with progressive trenching is the most efficient and cost-effective method of dewatering fine-grained dredged material. Other methods investigated were the use of underdrains, horizontal or vertical sand drains, mechanical agitation, electro-osmosis, and vacuum well pointing. While some of these methods produce higher rates of dewatering, they incur high capital and operating costs and are not cost-effective unless constraints, such as time available, preclude natural dewatering.

4.3.3. Dredging HSB and IC Sediments

Overview-- Channel dredging will proceed in the following sequence:

1) construct necessary access roads along HSB,

2) clear trees and other debris from the channel and bank edges with a crawler-mounted crane operating from the access road and a small barge-mounted crane operating in areas inaccessible from the road,

3) dispose of the cleared debris in a landfill, and

4) hydraulically dredge the channel sediments and transport material via pipeline to the temporary disposal area.

For removing overbank material in Reach A of HSB, the following approach will be used:

1) clear vegetation from the overbank,

2) grub all root systems,

3) remove contaminated sediment with a dragline,

4) construct haul roads as necessary as operation progresses into overbank,

5) dispose of contaminated tree material in landfill, and

6) dispose of contaminated sediment by landfilling in the TDMDA, or by burial in an off-site mine.

Channel Dredging--A conventional basket cutterhead dredge such as the 14-inch Ellicott 770 could be employed to dredge HSB and IC channel sediments. Dredging will commence at HSB Mile 5.6 as soon as sufficient channel is cleared and proceed downstream, following the snagging operation.

Due to the long discharge distance to the TDMDA (12.5 miles from IC Mile 0.0) a total of 11 booster pumps will be required in the discharge line. Use of electric boosters is recommended, as they are much more easily adapted to an integrated central control system to maintain steady flow in the discharge line. A temporary power line carrying primary voltage (43 kv) would be required along the access road to provide power for the boosters. Spacing power poles at 175 foot intervals and installing conventional street lights on each would provide adequate lighting along the access road for evening shift work and pipeline inspection.

Overbank Removal--The critical overbank area indicated in Figure 6 consists of approximately 25 acres and contains an estimated 61 percent of the total DDTR in the HSB-IC system. Its removal will require excavation and disposal of 121,600 cubic yards of sediment. The non-critical overbank areas of Reach A contains approximately 4.3 percent of the total DDTR in the HSB-IC system. In order to remove this 4.3 percent, approximately 235 acres of overbank will have to be cleared and grubbed, and 1,122,400 cubic yards of sediment will have to be excavated.

Removal of the overbank sediments will require clearing all vegetation and grubbing all root systems. Disposal of cleared uncontaminated timber and debris will be provided by the contractor hired for clearing. Removal of the contaminated sediments to a depth of 3 feet can be accomplished simultaneously with grubbing by a small dragline, operating

on mats if necessary. Root material will be disposed of in a landfill adjacent to the TDMDA. Overbank sediments will be disposed of in a diked portion of the TDMDA or by containment in an abandoned mine.

Work Scheduling--Work schedules in HSB and IC will have to be coordinated with operations of the Test and Evaluation Directorate (T and ED) at Test Area 1 located immediately south of Huntsville Spring Branch. Based on past operation of Test Area 1, the following estimates of work stoppage during normal work time (0800 to 1630 hours, Monday through Friday) can be expected if range operations are not curtailed during dredging:

1) eastern half of Reach A, 0 percent;

2) western half of Reach A, 25 percent;

3) Reach B and Reach C north of Centerline Road, 65 percent; and

4) Reach C south of Centerline Road, 61 percent.

Based on these estimates an evening shift would be required in Reaches B and C if Test Area 1 operations are not to be seriously impacted. Work in Reach A can be conducted during normal work hours without serious impact on range operations, provided contractor personnel can be evacuated during hazardous tests. As this will result in an estimated 25 percent work stoppage in the western half of Reach A, work in that reach may be more productive on an evening shift.

4.3.4 Permanent Disposal of Dredged Material

The following methods were considered for permanent disposal of DDTR-contaminated dredged sediments:

1) Use of TDMDA as a permanent landfill,
2) Disposal in an abandoned mine,
3) Incineration of the sediments, and
4) Disposal in an off-site secure landfill.

Use of off-site secure landfills was eliminated due to high transportation and disposal costs of using existing hazardous waste landfills, and the fact that constructing a new secure landfill does not hold any significant advantages over disposal in the TDMDA. Incineration was eliminated due to high costs and excessive energy consumption.

Permanent disposal in the TDMDA will provide an acceptable degree of isolation for the contaminated sediments. It has the advantages of maintaining DDTR contamination in a localized area and low cost. The only significant disadvantage posed would be the loss of that area for other future land uses.

Mine disposal may also provide for secure permanent disposal of the contaminated sediments, though at a significantly higher cost than

disposal in the TDMDA. A disadvantage of this disposal option would be the potential for leakage of contaminated material from haul trucks. A thorough hydrogeologic study of the proposed mine would be required before implementing this disposal option.

4.3.5 Monitoring Program

Dredging Operation--Monitoring of the dredging operation will be necessary to insure accuracy and control of sediment dredging. Automatic water sampling should be conducted both upstream and downstream from the dredge. Parameters tested should include turbidity, suspended sediment, total DDTR, and heavy metals. Influent and effluent of the return water treatment system should be analyzed daily for these same parameters. Daily inspections of the TDMDA will be required.

Additionally, careful control of dredging operations will be necessary to insure that no areas designated for removal are missed or skipped. This is critical to the complete removal of contaminated material.

Long-Term Disposal Site Monitoring--Groundwater and leachate monitoring systems will be installed at the TDMDA. Total DDTR and water level data should be recorded at each sampling location for an extended period (30 year post-closure care is provided for in cost estimates). Inspections of the closed site should be conducted once or twice yearly to check the integrity of the cover and fence.

4.3.6 Predicted Environmental Impacts of Dredging and Disposal

Dredging--The impacts of dredging are associated with

1) road construction,

2) mechanical removal of sediments and snag habitats, and

3) water quality degradation.

The dredge access roadway would extend about 63,300 linear feet and impact 71.5 acres. Almost 40 percent of this acreage is occupied by aquatic or wetland habitats. Approximately one-half of the total "edge" habitat along HSB and IC will be altered. This habitat has high wildlife value.

Mechanical removal of snags and sediment will result in the loss of existing aquatic communities. These can recover over time but may take several years. Loss of snags and the unique habitats they provide in the system represents an even longer term loss.

Fish will likely move to avoid the dredge. Once dredging in an area is completed fish will return but will find reduced food available probably for several years. Also, what food is available may be contaminated by residual DDTR.

Water quality will be degraded to some extent by turbidity and suspension of DDTR. However, the relatively low flows in HSB are not expected to transport excessive DDTR downstream. An analysis of DDTR transport by the dredge plume from HSB has been made. The results indicate that more DDTR is moving out of HSB annually under existing uncontrolled conditions than will be moved in the dredge plume. Nevertheless, the dredging will cause some increase in the DDTR transported downstream in the short term. The majority of the plume will settle prior to reaching the Tennessee River and be subsequently removed as the dredge progresses downstream.

After dredging there will be some increase in suspended solids loadings due to erosion. This will continue until the exposed overbank areas can be stabilized.

If substantial quantities of DDTR are missed due to poor control of the dredging operations, contamination could continue until this was somehow mitigated. The extent of this impact would be dependent on how much DDTR was missed. Good quality control over dredging operations should minimize this risk.

Disposal of Dredged Material--Construction of the temporary dredged material disposal area will result in the loss of 187 acres of upland habitat. During the dredging and dewatering phase, wildlife could experience some contamination from use of this area. To minimize this, the area should be covered and stabilized as soon as practical following dredging.

4.4 OUT OF BASIN DIVERSION OF HSB

4.4.1 Introduction

The diversion of HSB from a point upstream from the contaminated area directly to the TR would greatly reduce hydraulic transport of DDTR out of HSB. Headwater flow in the contaminated HSB channel will be limited to that created by local runoff from several small drainage basins lying to the north. Such a diversion will facilitate further actions for mitigation of DDTR contamination in HSB. Removal alternatives can be implemented with negligible downstream transport of DDTR under the reduced flow conditions. Alternatives to contain contaminated HSB sediments in place can also be implemented in conjunction with an out-of-basin diversion of HSB.

4.4.2 Diversion Alignment

The alignment for the out-of-basin diversion of HSB is illustrated in Figure 7. Alignment sectors are delineated on the basis of whether or not alternate alignments are considered within the sector.

4.4.3 Design Criteria

Both the main diversion channel and the McDonald Creek cut-off channel are designed for the 100-year headwater flood in HSB, a discharge of

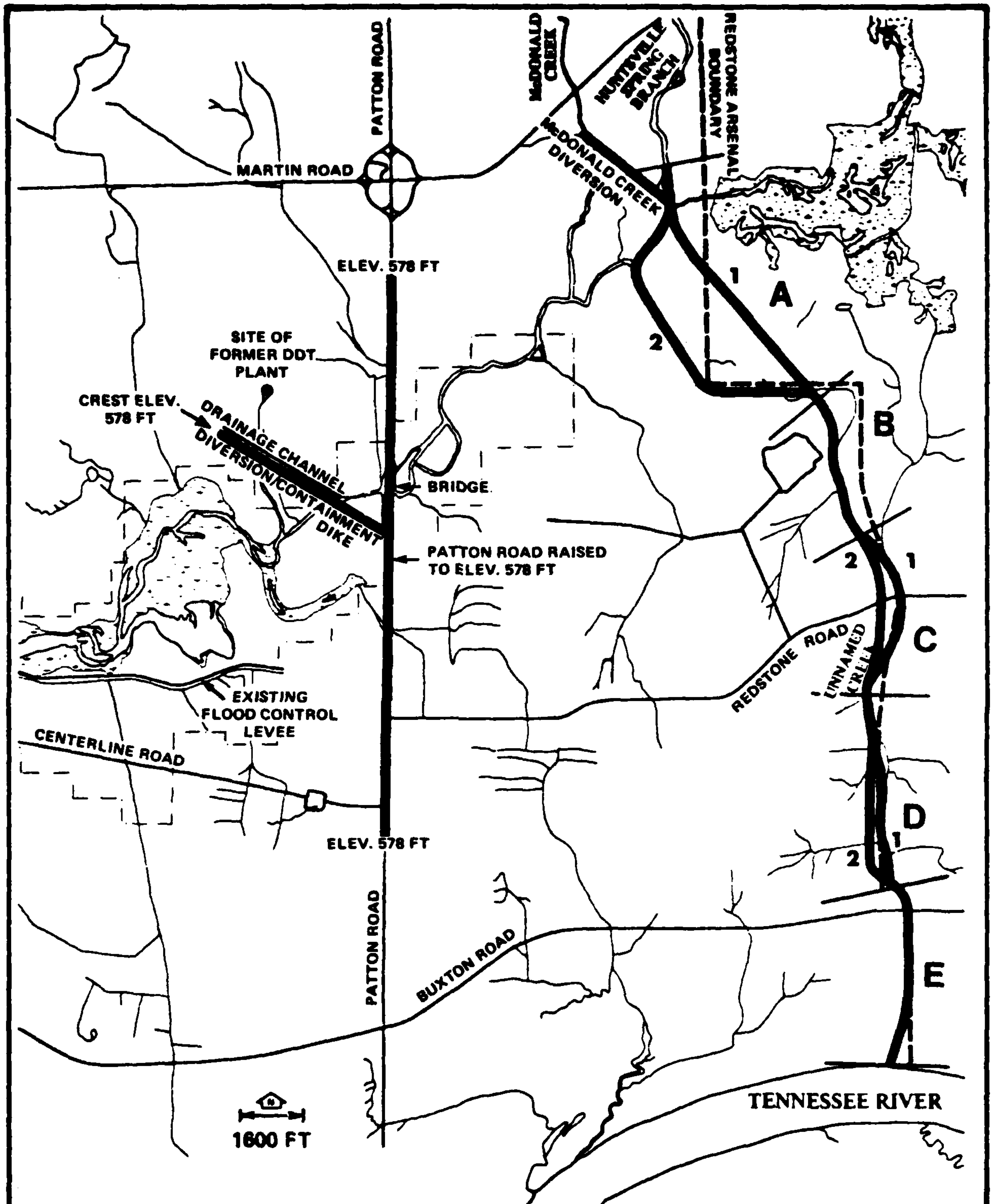

FIGURE 7. Proposed Alignment for Out-of-Basin Diversion of Huntsville Spring Branch

SOURCE: WATER AND AIR RESEARCH, INC., 1980

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approximately 20,500 cfs. A diversion/containment dike will be constructed by raising Patton Road and constructing a dike between Patton Road south of HSB and high ground to the northwest, as shown in Figure 7. A bridge will be built over the existing HSB channel at Patton Road so that local runoff from drainage basins north of HSB can flow via the HSB channel to the diversion channel. This reversal of flow in the HSB channel would not require channel improvement, as the slope of the existing channel between the diversion point and Patton Road is slight and the flows will be small. The raising of Patton Road will serve a two-fold purpose, as it will constitute part of the diversion/containment dike and will provide access to the southern portion of RSA under flood conditions. Dike elevations are designed for the 100-year flood stage on the TR south of RSA, approximately elevation 575. The design crest of the dike system is elevation 578, allowing 3 feet of freeboard in the design flood. No overflow structures will be necessary in the dike. A conservative 3:1 sideslope is used for all dike designs in the absence of detailed geotechnical information.

4.4.4 Construction

The out-of-basin diversion will require excavation of approximately 4,045,000 cubic yards, an estimated 7 percent of which will be rock. Excavation of the McDonald Creek cut-off channel will involve approximately 61,000 cubic yards. The containment dike system will require placement of approximately 598,000 cubic yards.

Work Scheduling-- Little or no restriction on work hours is expected for any construction associated with the out-of-basin diversion of HSB, as the areas involved do not seriously conflict with RSA operations.

4.4.5 Predicted Environmental Impacts of Out-of-Basin Diversion

Indian Creek--Routing Huntsville Spring Branch out of the Indian Creek Basin will reduce the flow in Indian Creek about 61 percent. Water levels in IC will not change since they are controlled by Wheeler Reservoir. The allochthonous detrital load in IC below the HSB confluence will be reduced. However, sufficient load should remain to sustain detrital food chains now existing.

Unnamed Creek--Construction of the out-of-basin diversion channel will result in the replacement of 3.6 acres of aquatic canal habitat, 21.9 acres of bottomland hardwood swamp, and 267 acres of upland habitat with 181 acres of similar but wider aquatic canal habitat and 111.5 acres of upland dike habitat. Most of the present habitat is already environmentally degraded. Excavation of the diversion channel is expected to contact bedrock in at least two areas. Exposure of the bedrock increases the potential for aquifer recharge. Since urban runoff from Huntsville can be expected to be degraded at times, the possibility for some groundwater contamination exists. However, it appears that the aquifer discharges to the Tennessee River in this area. This would minimize the areal extent of contamination should it occur.

Muddy Cave, known habitat of the troglobitic southern cavefish, *Typhlychthes subterraneus*, exists about one-half mile east of the proposed diversion route. No adverse impact on the cave is anticipated.

4.5 WITHIN-BASIN DIVERSION OF HSB

4.5.1 Introduction

A within-basin diversion is proposed to bypass HSB around the most heavily contaminated area between HSB Miles 4.1 and 5.6. Together with a containment dike around the most heavily contaminated area as illustrated in Figure 8, such a diversion will eliminate hydraulic transport of DDTR from this heavily contaminated area. Further removal or containment actions within the diked area will also be facilitated. The flow of HSB will reenter the existing channel at HSB Mile 3.4. Mitigating actions downstream from that point will consist of dredging the HSB and IC channels.

4.5.2 Diversion Alignment

The alignment for the within-basin diversion is illustrated in Figure 8. Though this alignment encroaches on the margin of the safety fan for Test Area 1, use of this corridor is generally compatible with T and ED operations there.

4.5.3 Design Criteria

Design criteria for the diversion channel is the 100-year headwater flood in HSB, a discharge of approximately 20,500 cfs. The containment dike is designed not to be overtopped by the 100-year flood stage on the TR of approximately 575 feet. The crest elevation of the dike is 578 feet, allowing 3 feet of freeboard over the design flood stage. A 3:1 sideslope is used in the absence of detailed geotechnical information. Drainage channels on the northwest and northeast sides of the containment dike are designed to carry runoff in excess of that resulting from the 10-year, 90-minute precipitation event. This duration corresponds to the time of concentration of the largest basin drained by the channels. Flows in excess of the 10-year storm would be contained by the dike and adjacent hillside.

4.5.4 Construction

The within-basin diversion will require excavation of approximately 1,177,500 cubic yards of material. The western and eastern runoff interception channels will require excavation of 53,000 and 15,000 cubic yards respectively. Total length of the within-basin diversion channel is 13,500 feet. Construction of the diversion/containment dike will require the placement of approximately 1,784,000 cubic yards of fill. An estimated 65 percent of this fill can be obtained from material excavated from the diversion and runoff interception channels. The remainder will have to be hauled from an off-site borrow area. Total length of the containment dike is 13,500 feet. The existing flood control levee

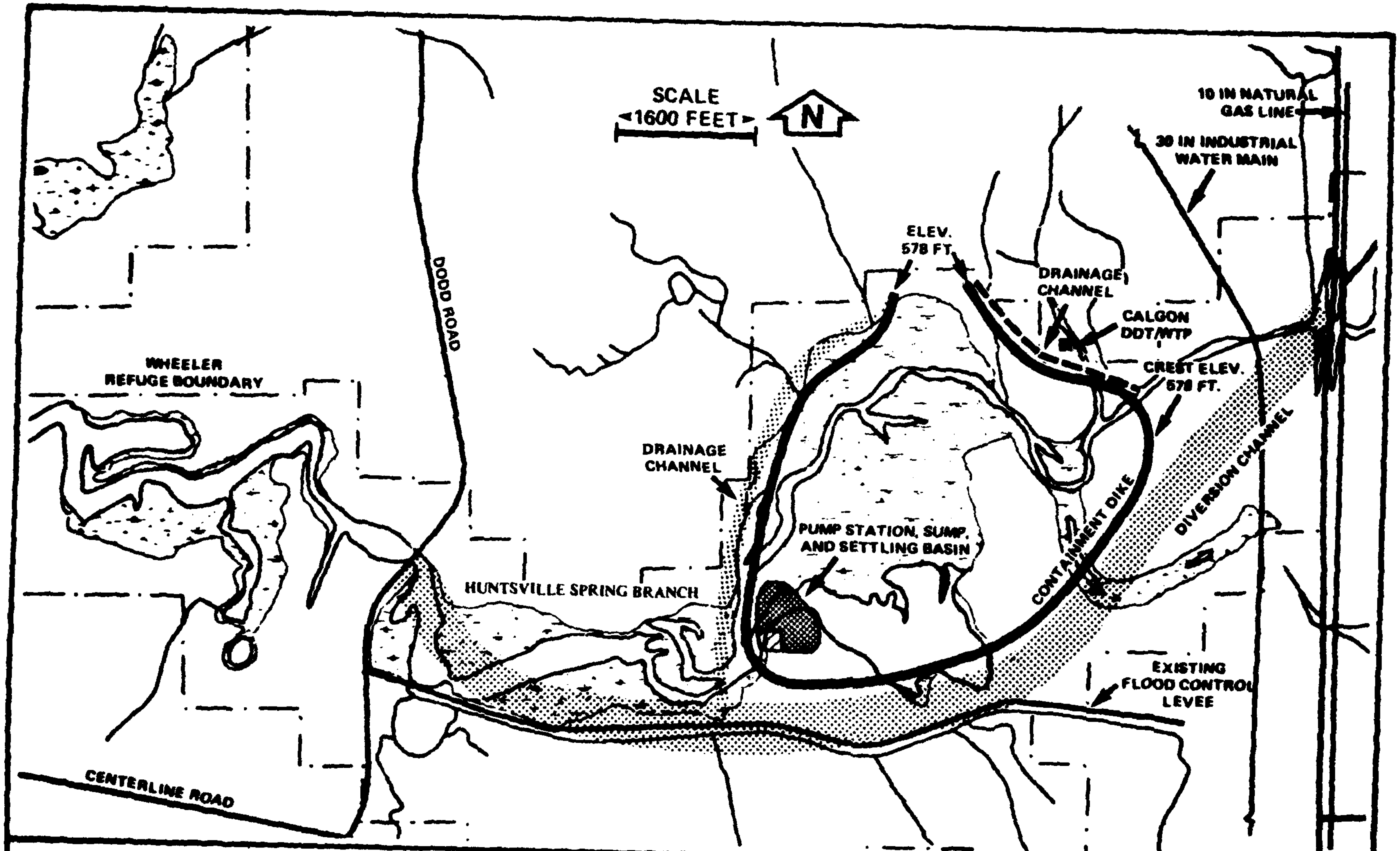

FIGURE 8. Proposed Alignment of the Within-Basin Diversion and Diversion/Containment Dike

SOURCE: WATER AND AIR RESEARCH, INC., 1980

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between HSB and Test Area 1 would be reconstructed and stabilized by grassing or riprap, as necessary, in areas where the diversion channel contacts it.

Work Scheduling--The westernmost extreme of construction activity barely encroaches on the safety fan of Test Area 1. Work stoppage within that portion of the safety fan is estimated at 25 percent of normal working hours. Due to the limited amount of activity involved in the restricted area, work stoppage should be minimal and a normal work shift can be employed throughout the project.

4.5.5 Predicted Environmental Impacts of Within-Basin Diversion

The conversion of a portion of HSB from a meandering stream to a shorter, straighter channel will result in a higher nutrient and suspended solids load downstream. However, since the IC system does not appear to be nutrient limited the impact will probably be insignificant.

4.6 IN-PLACE CONTAINMENT/STABILIZATION OF CONTAMINATED SEDIMENTS

4.6.1 Introduction

Containment or stabilization of contaminated sediments *in situ* can be effectively implemented only in conjunction with a diversion of flow in HSB. The containment technique should stop the migration of DDTR from HSB and diminish its bioavailability in order to be effective in the long term. Several containment methods were evaluated. Enclosing the highly contaminated areas of HSB within a dike and applying cover material over the channel sediments was found to be the most effective. Containment alternatives based on this approach are discussed for the within-basin and out-of-basin diversions. The possibility of groundwater contamination associated with this technique is minimal due to the immobility of DDTR in the sediments and evidence that HSB is a discharge area for local groundwater.

4.6.2 Containment with Out-of-Basin Diversion of HSB

Introduction--The highly contaminated sediments between HSB Miles 2.4 and 5.6 will be partially isolated by the out-of-basin diversion dike shown in Figure 7. Flow from HSB and runoff from basins to the northeast of the contaminated area will be diverted by these structures to the out-of-basin diversion channel. If no additional containment is provided, the contaminated area would still be subjected to runoff from local drainage basins to the north of the contaminated area and flows resulting from fluctuations of the Wheeler Reservoir pool. A dike and interception channel constructed along the northern edge of the contaminated area, as shown in Figure 9, would exclude these flows from the area and further isolate DDTR contamination upstream of Dodd Road. A settling basin, pumping station, and floodgate would be required to handle runoff from the area. A further degree of isolation will be gained by applying cover material over contaminated sediments in the HSB channel and overbank.

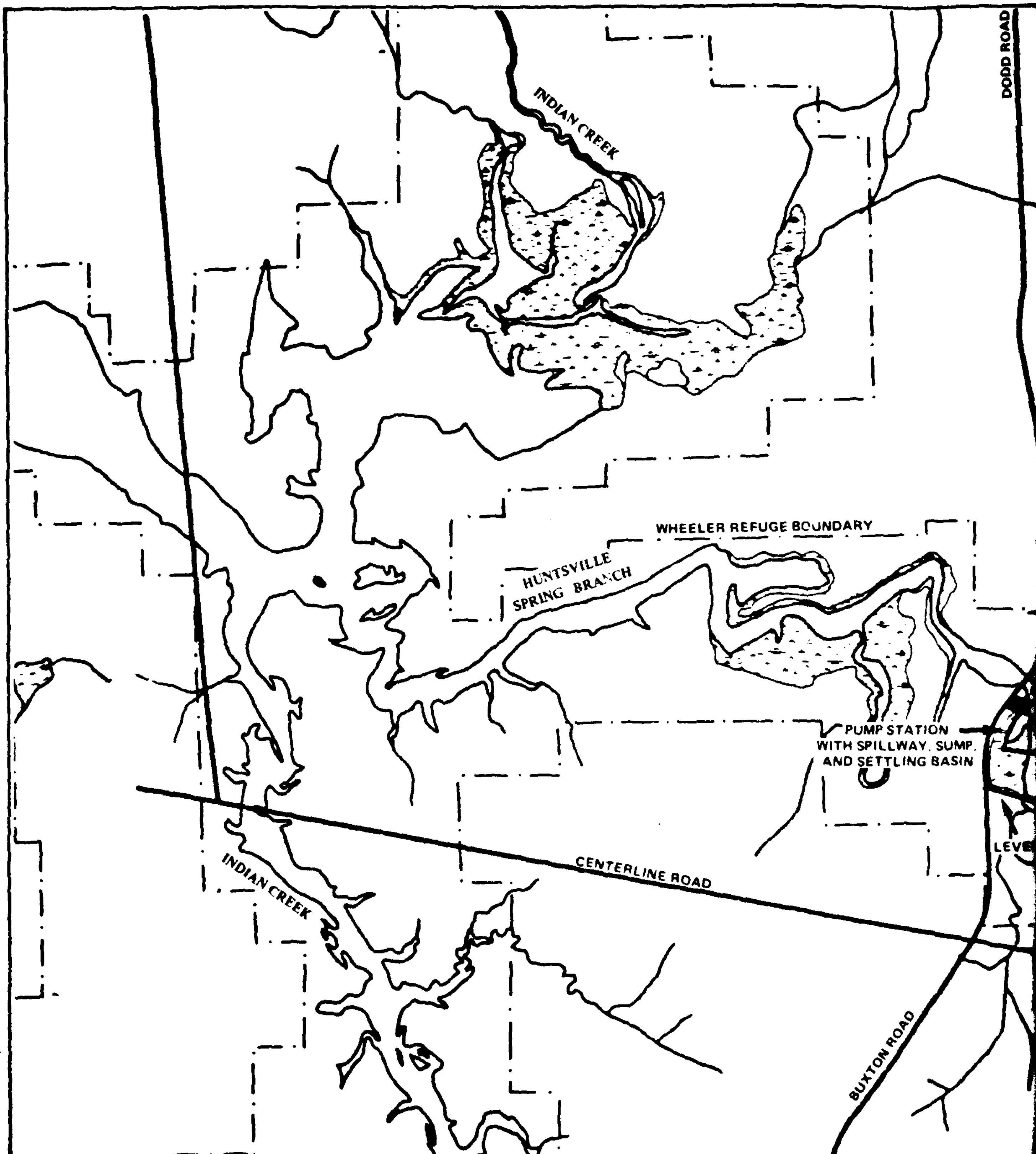
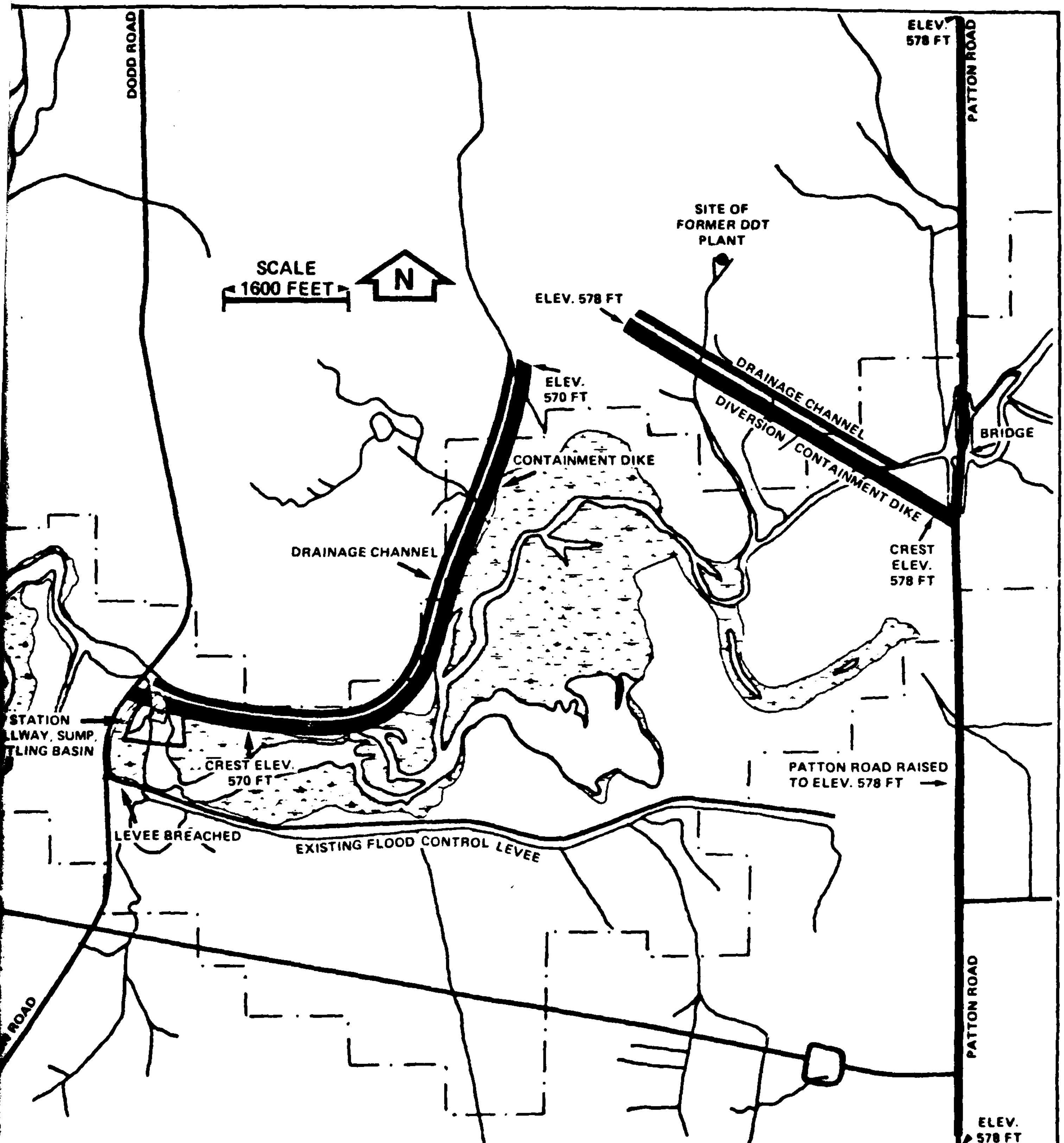


FIGURE 9. Containment Dike Plan for Out-of-Basin Diversion of Huntsville Spring Branch

SOURCE WATER AND AIR RESEARCH, INC., 1980



U.S. ARMY CORPS OF ENGINEERS, MOBILE DISTRICT
Engineering and Environmental Study of DDT Contamination of Huntsville Spring Branch, Indian Creek, and Adjacent Lands and Waters,Wheeler Reservoir, Alabama

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Design Criteria--Crest elevation of the containment dike will be 570 feet. Elevations in excess of this would be useless, as the area floods from the south when the Wheeler Reservoir pool exceeds an elevation of 568 feet. The dike and channel should be constructed into the hillside to an extent sufficient to provide fill for the dike and adequate slope along the length of the channel. Flows in excess of that generated by the 10-year 90-minute precipitation event will be accommodated by the channel and dike. Cover applied to the HSB channel sediments and overbank will consist of a minimum of 6 inches of compacted clay underlying 18 inches of soil suitable for supporting stabilizing shallow rooted vegetation.

Construction--Construction of the containment dike and drainage channel will be required before application of the final cover. Total length of the dike and channel is 8,000 feet, requiring placement of 153,700 cubic yards of fill for the dike and excavation of 86,500 cubic yards for the channel. The total capacity required for the pumping station is 4.0 MGD. Since the pumping station presently on the flood control levee north of Test Area 1 will no longer be required, those pumps can be utilized at the proposed pumping station. The existing dike would then be breached and the runoff from Test Area 1 would be pumped by the new station.

The HSB channel must be cleared of snags and debris before application of the cover. Covering the critical overbank area will require the clearing and grubbing of 25 acres. Application of final cover to these areas will require the hauling and placement of approximately 309,100 cubic yards of fill. If the non-critical overbank is to be covered 235 acres will have to be cleared and grubbed, and approximately 758,00 cubic yards of fill hauled and placed. The final cover will be stabilized with a suitable shallow-rooted vegetative cover. All borrow material will be hauled from the out-of-basin diversion. Available borings along the diversion alignment indicate that excavated material will be suitable for cover application.

Work Scheduling--Work schedules in the containment area will have to be coordinated with operations of the T and ED at Test Area 1. Based on past operation of Test Area 1, work stoppage will not be necessary upstream from HSB Mile 3.9, but will amount to 25 percent of normal working hours (0800 to 1630, Monday through Friday) downstream from Mile 3.9. The work stoppage will have to be figured into construction costs or be circumvented by employing an evening shift.

4.6.3 Containment With Within-Basin Diversion Of HSB

Introduction--A within-basin diversion will require a dike on the north side of the channel to divert and exclude flow in HSB from the old channel. By raising this dike and extending it such that the most highly contaminated area is completely enclosed, as shown in Figure 8, that area will be isolated from surrounding surface water. Precipitation incident on the enclosed area can be removed by a pumping station. Application of a stable cover over the contaminated channel sediments will provide a further degree of DDTR isolation within the containment area.

Design Criteria--Since the containment dike for the within-basin diversion is an integral part of the diversion, its design and construction is discussed with the diversion in Section 4.5.

Construction--Construction associated with the containment dike is summarized in Section 4.5.4. Covering the HSB channel sediments within the containment area will require snagging and clearing of the channel. Clearing and grubbing of 25 acres will be required in the critical overbank area. Final cover over these areas will require hauling and placement of 175,000 cubic yards of fill. If the non-critical overbank is covered, 160 acres will have to be cleared and grubbed and 516,300 cubic yards of fill hauled and placed. Final cover will be stabilized with a suitable shallow-rooted vegetative cover.

Work Scheduling--Work scheduling associated with the containment is discussed in Section 4.5.4.

4.6.4 Predicted Environmental Impacts of Containment/Stabilization of Contaminated Sediments

The area isolated for containment is largely a wetland system. If only the HSB channel and critical overbank are filled, the remainder of the area can be expected to become drier with associated species shifts. Lower spots within the area will become isolated pools or ponds. If the entire area is covered, including the non-critical overbank, the existing contaminated wetland system will be converted to a non-contaminated upland.

4.7 AREA-WIDE ENVIRONMENTAL MONITORING

A program of area-wide environmental monitoring will be required following implementation of any alternative in order to assess the effectiveness of the alternative by monitoring conditions during the preliminary recovery period. The proposed program would cover a period of four years following completion of clean-up activities, after which additional monitoring would be implemented as determined necessary. Surveys and DDTR analysis should include fish in IC and the TR; sediments in HSB, IC, and the TR; water in HSB; and non-fish vertebrates in and around HSB and IC.

4.8 LEGISLATION, REGULATIONS, AND PERMITTING

Actions proposed under alternatives for mitigation of DDTR in HSB and IC may be subject to regulation under the following legislation:

1) Clean Water Act,
2) River and Harbor Act of 1899,
3) National Environmental Policy Act,
4) Fish and Wildlife Coordination Act of 1934,
5) Resource Conservation and Recovery Act of 1976,
6) Hazardous Waste Transportation Act of 1974,
7) Endangered Species Act of 1973,

8) Section 26a of the Tennessee Valley Authority Act,
9) Various Historic and Archaeological Data Preservation Laws,
10) Alabama Hazardous Wastes Management Act of 1978,
11) Alabama Air Pollution Control Act of 1971,
12) Occupational Safety and Health Administration Legislation,
13) Executive Order 11988, and
14) Executive Order 11990.

4.9 PROPOSED ALTERNATIVES

4.9.1 Alternative A: Natural Restoration

With this alternative, mitigation of DDTR contamination would be left to natural processes. The key question with this alternative is will the situation get better or worse if left alone? For the situation to improve, one of three things must occur. Either

1) the DDTR must be degraded to harmless compounds, or

2) the DDTR must become isolated in some manner from the rest of the environment, or

3) the DDTR must be flushed out of the system.

Based on the known persistence of DDTR, particularly at the concentrations found in HSB, the natural degradation rate will be slow. Half-life may easily be on the order of 20 to 30 years. If this is true, one would expect to have in excess of 100 tons of DDTR in this system 60 years from now. Thus, natural degradation appears to be only a very long term hope at best.

Natural isolation of the material from the rest of the environment may be possible. The most likely mechansism would be natural sediment deposition which could bury the DDTR. However, the old DDT plant has been closed for over 10 years and 47 percent of the DDTR is still within the top 6 inches of sediment, 86 percent within the top 1 foot. Thus, if significant natural sediment deposition is occurring, it is not readily apparent.

The third possible means of natural restoration would be for the DDTR to be flushed out of the system. Given the mass of DDTR in the HSB-IC system and the current estimates of transport rates, it appears that hundreds of years would be required to flush the system naturally. Even if this were to occur, the positive effects on the HSB-IC system would be more than offset by the negative impacts on the Tennessee River.

A further negative factor in assessing the potential effectiveness of this alternative is the relatively small amount of DDTR required to cause significant contamination. Currently, only 1 percent of the total DDTR is in Indian Creek and fish are contaminated. If the substantial storehouse of DDTR upstream is left uncontrolled, the threat always exists that contamination of IC will be maintained or even made worse.

It may be that, given enough time, sufficient DDTR will move into the TR to cause even worse contamination problems there.

On a more positive note, there is the suggestion in some of the bird population data from Wheeler National Wildlife Refuge that some species adversely impacted by DDTR have been recovering in recent years. However, this recovery is not observed in many species. Also, it is not known whether the apparent recovery in some species is due to local, regional, or areawide conditions.

The short-term risk of natural restoration is relatively low in that the situation does not appear to be rapidly worsening. Thus, it would be possible to tentatively employ this alternative coupled with continued monitoring and status reports. This would allow additional time during which more definitive information could be gathered to determine contamination trends. Such a monitoring program should include measurement of DDTR levels in fish, sediment, water and to a more limited extent in animals and birds. Cost would be dependent on intensity and frequency of sampling but is roughly estimated at $600,000 per year.

The selection of the natural restoration alternative would have the advantage of providing time during which new and/or currently unproven technology could be developed which might result in a more cost effective mitigation plan. However, there is no guarantee that such a plan would materialize.

In summary, the success of the natural restoration alternative depends on natural actions that range in probability from very unlikely to, at best, possible. On the positive side, it appears that conditions are not rapidly changing and the tentative selection of this alternative would not present a high risk for a significantly worsened situation.

4.9.2. Alternative B: Dredging and Disposal

HSB and IC channel sediments would be hydraulically dredged to a depth of 3 feet. The critical overbank area would be dragline dredged to a depth to a depth of 3 feet. Non-critical overbank sediments may or may not be dredged. Hydraulically dredged sediments would be pumped to the TDMDA, where they would be dewatered. Dragline-dredged sediments would be truck-hauled to the TDMDA. The most feasible means of permanent disposal of contaminated sediments is closure of the TDMDA as a permanent landfill.

Implementation Summary--

1) Conduct cultural resources survey of impacted areas and implement necessary actions to recover or preserve valuable sites.

2) Construct temporary dredged material disposal area (TDMDA).

3) Secure lease on return water treatment system and set up at TDMDA

4) Clear and grub critical overbank area, dredge those sediments with a dragline to a depth of 3 feet, and dispose of in TDMDA

5) Construct access roads along the channel and install 43 kv primary voltage power line with lighted poles

6) Clear all snags and debris from HSB and IC channels

7) Acquire 12, 14-inch booster pumps and install 11 of them at 6,000 foot intervals along access road (one used as spare)

8) Implement monitoring of dredging operation

9) Dredge HSB and IC channels with 14-inch cutterhead hydraulic dredge to a depth of 3 feet, beginning at HSB Mile 5.6. Pump dredged sediments to TDMDA

10) Dewater dredged material in the TDMDA

11) Permanently dispose of DDTR-contaminated sediments by closing TDMDA as a landfill

12) Implement areawide environmental monitoring and long-term monitoring and maintenance of the permanent disposal site.

<u>Options Available With Alternative B</u>--

1) Remove noncritical overbank sediments of Reach A to a depth of 3 feet

2) Delete carbon adsorption from return water treatment system

3) Remove dewatered sediments from TDMDA and dispose of in an abandoned mine

4) Delete dredging of Reach C (IC)

5) Delete dredging of Reaches B and C (HSB Mile 2.4 to IC Mile 0.0)

<u>Cost Summary for Alternative B</u>--The cost summary for Alternative B is in Table 8.

<u>Impact Summary for Alternative B</u>--The environmental impacts of dredging and disposal have been discussed in Section 4.3.6.

With regard to Cultural Resources, dredging impacts a large number of high probability locations in the proximity of HSB and IC. There is presently no way to predict accurately how many sites are located in the alluvial bottomlands of IC and HSB, now inundated by Wheeler Reservoir. Disposal of dredged material will impact a relatively smaller area with a high probability for site locations, as indicated by the reconnaissance survey.

Table 8. Cost Summary for Alternative B (As Detailed in Table III-11 for Dredging Plan III)

Dredging Plan	Reaches Included*	Total Estimated Cost (Millions of Dollars)
I	A	27.04
II	A,B	38.66
III	A,B,C	68.16

Estimated Effect of Other Options on Cost Estimate (Millions of Dollars):

-Implement Noncritical Overbank Removal Option	+ 18.66
-Delete Carbon Adsorption From Return Water Treatment System	- 4.16
-Implement Mine Disposal (Plan III)	+ 15.51
(Including Disposal of Noncritical Overbank Sediments)	+ 43.37

4.9.3 Alternative C: Out-of-Basin Diversion and Removal of Contaminated Sediments

HSB would be diverted form 3 miles upstream of the highly contaminated area directly to the Tennessee River. Channel sediments between HSB Mile 2.4 and IC Mile 0.0 would be hydraulically dredged under near-zero flow conditions. The HSB channel between Miles 2.4 and 5.6 may be hydraulically dredged, or dredged with a dragline if the area is dewatered by construction of the containment dike illustrated in Figure 9. Critical overbank sediments would be dragline-dredged and non-critical overbank sediments may or may not be dredged.

Implementation Summary--

1) Conduct cultural resources survey of impacted areas and implement necessary actions to recover or preserve valuable sites.

2) Construct out-of-basin diversion of HSB and McDonald Creek cut-off channel.

3) Raise Patton Road to elevation 578 and construct dike northwest of Patton Road. This dike combination will serve as a diversion dike for HSB and will limit transport of contaminated sediments in HSB during removal operations

4) Construct TDMDA

5) Secure lease on return water treatment system and set up at TDMDA

6) Clear and grub critical overbank area, dredge those sediments with a dragline to a depth of 3 feet, and dispose of in TDMDA

7) Dredge HSB and IC channels by one of the two following methods:
   a) Hydraulic Dredging as summarized in items (5) through (9) of Section 4.9.2
   b) Construct western containment dike, drainage channel, and pumping station as shown in Figure 10 and excavate sediments within the containment area (HSB Miles 2.4 to 5.6) to a depth of 3 feet with a dragline. Dispose of sediments in TDMDA. Dredge sediments downstream from HSB Mile 2.4 hydraulically as summarized in items (5) through (9) of Section 4.9.2.

8) Dewater dredged material in TDMDA

9) Permanently dispose of DDTR-contaminated sediments by closing TDMDA as a landfill

10) Implement areawide environmental monitoring and long-term monitoring and maintenance of the permanent disposal site.

Options Available With Alternative C--

1) Remove noncritical overbank sediments to a depth of 3 feet

2) Delete carbon adsorption from return water treatment system

3) Remove dewatered sediments from TDMDA and dispose of in an abandoned mine.

4) Delete dredging of Reach C (IC)

5) Delete dredging of Reaches B and C (HSB Mile 2.4 to IC Mile 0.0)

6) Use alternate alignment for out-of-basin diversion to maintain it within RSA boundaries

Cost Summary--The cost summary for Alternative C is in Table 9.

Impact Summary--The environmental impacts of out-of-basin diversion and of dredging and disposal have been discussed in Sections 4.4.5 and 4.3.6.

With regard to Cultural Resources, Alternative C impacts a large number of high probability locations. All probable or potential sites in the proximity of HSB, IC, and the disposal area would be impacted by dredging associated with this alternative. In addition, the out-of-basin diversion route affects the largest number of known sites, as well as the greatest number of sites potentially eligible for the National Register.

4.9.4 Alternative D: Out-of-Basin Diversion and Containment of Contaminated Sediments

HSB would be diverted from 3 miles upstream of the highly contaminated area directly to the Tennessee River. Channel sediments between HSB Mile 2.4 and IC Mile 0.0 would be hydraulically dredged. A containment dike as illustrated in Figure 9 would be constructed. Channel and critical overbank sediments within the containment area would be covered with compacted clay and clean fill. Non-critical overbank sediments may or not be covered.

Implementation Summary--

1) Conduct cultural resources survey of impacted areas and implement necessary actions to recover or preserve valuable sites.

2) Construct out-of-basin diversion of HSB and McDonald Creek cut-off channel.

3) Raise Patton Road to elevation 578 and construct dike northwest of Patton Road. This dike combination will serve as a diversion dike for HSB and will help contain contaminated sediments in HSB.

4) Construct western containment dike, drainage channel and pumping station as shown in Figure 9.

Table 9. Cost Summary for Alternative C (As Detailed in Table III-14)

Dredging Method(s) Utilized	Total Estimated Cost (Millions of Dollars)
All Hydraulic Dredging	118.38
Dragline Dredging Between HSB Miles 2.4 and 5.6, Remainder Hydraulically Dredged	123.53
Estimated Effect of Other Options on Cost Estimate (Millions of Dollars):	
-Implement Noncritical Overbank Removal Option in Reach A	+ 18.66
-Delete Carbon Adsorption From Return Water Treatment System	- 4.16
-Implement Mine Disposal	+ 15.04
(Including Disposal of Overbank Sediments)	+ 43.37
-Delete Hydraulic Dredging of Reach C	- 17.94
-Delete Hydraulic Dredging of Reaches B and C	- 26.93
-Use Alternate Sector Routings to Keep Diversion within RSA Boundaries (i.e., Sectors A-2, B, C-2, D-2, and E)	+ 8.22*

*Cost increase is attributed almost entirely to the increased amount of bedrock expected to be encountered during excavation of the channel.

5) Clear and grub critical overbank area. Remove snags and debris from HSB channel.

6) Cover critical overbank and channel sediments within the containment area with a minimum of 6 inches of compacted clay and 18 inches of soil suitable for supporting vegetative cover.

7) Establish vegetative cover on placed fill.

8) Dredge contaminated channel sediments downstream from HSB Mile 2.4 as summarized in items (1) through (11) of Section 4.9.2

9) Implement areawide environmental monitoring and long-term monitoring and maintenance of the permanent disposal site.

Options Available With Alternative D--

1) Apply cover to entire overbank area within containment.

2) Delete carbon adsorption from return water treatment system.

3) Remove dewatered dredged sediments from TDMDA and dispose of in an abandoned mine.

4) Delete hydraulic dredging of Reach C (IC).

5) Delete hydraulic dredging of Reaches B and C (HSB Mile 2.4 to IC Mile 0.0).

6) Use alternate alignment for out-of-basin diversion to maintain it within RSA boundaries.

Cost Summary--The cost summary for Alternative D is in Table 10.

Impact Summary for Alternative D--The environmental impacts of out-of-basin diversion and of containment have been discussed in Sections 4.4.5 and 4.6.4.

With regard to Cultural Resources, Alternative D impacts a large number of high probability locations. All probable or potential sites in the proximity of HSB, IC, and the disposal area would be impacted by dredging or covering associated with this alternative. In addition, the out-of-basin diversion route affects the largest number of known sites as well as the greatest number of sites potentially eligible for the National Register. Construction of the dewatering dike north of HSB may impact additional sites in a high probability area.

4.9.5 Alternative E: Within-Basin Diversion and Removal of Contaminated Sediments

HSB would be diverted around the highly contaminated channel between Miles 3.9 and 5.6. A containment dike as illustrated in Figure 8 would

Table 1C. Cost Summary for Alternative D (As Detailed in Table III-17)

Areal Extent of Cover Application Within Containment	Total Estimated Cost (Millions of Dollars)
Channel and Critical Overbank Only	120.99
Channel and Entire Overbank	129.88

Estimated Effect of Other Options on Cost Estimate (Millions of Dollars):

-Delete Carbon Adsorption From Return Water Treatment System	- 4.16
-Implement Mine Disposal	+ 12.40
-Delete Hydraulic Dredging of Reach C	- 29.02
-Delete Hydraulic Dredging of Reaches B and C	- 40.63
-Use Alternate Sector Routings to Keep Diversion Within RSA Boundaries	+ 8.22

be constructed. HSB and IC channel sediments downstream from the containment area would be hydraulically dredged. Channel sediments within the containment area may be hydraulically dredged under near-zero flow conditions, or dragline dredged if the containment area is dewatered. Critical overbank sediments would be dragline dredged, and non-critical overbank sediments may or may not be dredged.

Implementation Summary--

1) Conduct cultural resources survey of impacted areas and implement necessary actions to recover or preserve valuable sites.

2) Construct within-basin diversion and diversion/containment dike.

3) Construct TDMDA.

4) Secure lease on return water treatment system and set up at TDMDA.

5) Clear and grub critical overbank area, dredge those sediments with a dragline to a depth of 3 feet, and dispose of in TDMDA.

6) Dredge HSB and IC channels by one of the two following methods:
a) Hydraulic dredging as summarized in items (5) through (9) of Section 4.9.2.
b) Dragline dredge HSB channel sediments within the containment area (HSB Miles 4.0 to 5.6) to a depth of 3 feet. Dispose of sediments in the TDMDA. Dredge sediments downstream from HSB Mile 4.0 hydraulically as summarized in items (5) through (9) of Section 4.9.2.

7) Dewater dredged material in TDMDA.

8) Permanently dispose of DDTR-contaminated sediments by closing TDMDA as a landfill.

9) Implement areawide environmental monitoring and long-term monitoring and maintenance of the permanent disposal site.

Options Available With Alternative E--

1) Remove non-critical overbank sediments to a depth of 3 feet.

2) Delete carbon adsorption from return water treatment system.

3) Remove dewatered sediments from TDMDA and dispose of in an abandoned mine.

4) Delete dredging of Reach C (IC).

5) Delete dredging of Reaches B and C (HSB Mile 2.4 to IC Mile 0.0).

Cost Summary--The cost summary for Alternative E is in Table 11.

Impact Summary for Alternative E--The environmental impacts of within-basin diversion and of dredging and disposal have been discussed in Sections 4.5.5 and 4.3.6.

With regard to Cultural Resources, all probable or potential sites in the proximity of HSB, IC, and the disposal area would be impacted by dredging associated with Alternative E. In addition, the within-basin diversion channel and dikes will impact one reported site and possibly other potential sites.

4.9.6 Alternative F: Within-Basin Diversion and Containment of Contaminated Sediments

HSB would be diverted around the highly contaminated channel between Miles 3.9 and 5.6. A containment dike as illustrated in Figure 8 would be constructed. HSB and IC channel sediments downstream from the containment area would be hydraulically dredged. Channel and critical overbank sediments within the containment area would be covered with compacted clay and clean fill. Non-critical overbank sediments may or may not be covered. An option is given to construct a disposal area within the diversion/containment dike for sediments dredged downstream from HSB Mile 3.9.

Implementation Summary--

1) Conduct Cultural resources survey of impacted areas and implement necessary actions to recover or preserve valuable sites.

2) Construct within-basin diversion and diversion/containment dike.

3) Clear and grub critical overbank area. Remove snags and debris from the HSB channel.

4) Cover critical overbank and channel sediments within the containment area with a minimum of 6 inches of compacted clay and 18 inches of soil suitable for supporting vegetative cover.

5) Establish vegetative cover on placed fill.

6) Dredge contaminated sediments downstream from HSB Mile 2.4 as summarized in items (1) through (11) of Section 4.9.2.

7) Implement areawide environmental monitoring and long-term monitoring and maintenance of the permanent disposal site.

Options Available With Alternative F--

1) Use within-basin diversion containment area for disposal of dredged material.

Table 11. Cost Summary for Alternative E (As Detailed in Table III-20)

Dredging Method(s) Utilized	Total Estimated Cost (Millions of Dollars)
All Hydraulic Dredging	87.31
Dragline Dredging Between HSB Miles 2.4 and 5.6, Remainder Hydraulically Dredged	88.07
Estimated Effect of Other Options on Cost Estimate (Millions of Dollars):	
-Implement Noncritical Overbank Removal Option in Reach A	+ 18.66
-Delete Carbon Adsorption From Return Water Treatment System	- 4.16
-Implement Mine Disposal	+ 16.51
(Including Disposal of Overbank Sediments)	+ 43.37
-Delete Hydraulic Dredging of Reach C	- 29.02
-Delete Hydraulic Dredging of Reaches B and C	- 40.63

2) Cover non-critical overbank sediments

3) Delete carbon adsorption from return water treatment system

4) Remove dewatered sediments from TDMDA and dispose of in an abandoned mine

5) Delete dredging of Reach C (IC)

6) Delete dredging of Reaches B and C (HSB Mile 2.4 to IC Mile 0.0)

Cost Summary--The cost summary for Alternative F is in Table 12.

Impact Summary for Alternative F--The environmental impacts of within-basin diversion and of containment have been discussed in Sections 4.5.5 and 4.6.4.

With regard to Cultural Resources, all probable or potential sites in the proximity of HSB, IC, and the disposal area would be impacted by dredging or covering associated with Alternative F. In addition, the within-basin diversion channel and dikes will impact one reported site and possibly other potential sites.

5.0 PREDICTED EFFECTIVENESS OF MITIGATION ALTERNATIVES

There are several measures by which the effectiveness of a mitigation alternative can be estimated. These include the following:

1) Percent or mass of contamination contained in-place
2) Percent or mass of contamination removed and disposed of
3) Residual contamination left in the system and the potential for its mitigation by natural processes
4) Degree of short-term transport of DDTR downstream during implementation
5) The time required for DDTR levels in biota (particularly fish) to reach acceptably low levels.

The distinction is made between items 1) and 2) because there is an inherent difference in effectiveness between the two. Covering contaminated sediments in place can be assumed to be near 100 percent effective, provided proper long-term maintenance is implemented. Removing and disposing of contaminated sediments is subject to the following shortcomings which preclude its being 100 percent effective:

- Some degree of residual contamination will inevitably be left behind

- Short-term transport of DDTR to the TR will occur to an undetermined extent during dredging

- The potential for leakage or spillage during removal operations.

Table 12. Cost Summary for Alternative F (As Detailed in Table III-23)

Disposal Option Implemented	Total Estimated Cost (Millions of Dollars)
Use TDMDA	
-excluding overbank covering option	86.92
-including overbank covering option	92.96
Use Within-Basin Diversion Containment Area for Disposal Area	88.86
Estimated Effect of Other Options on Cost Estimate (Millions of Dollars):	
-Delete Carbon Adsorption From Return Water Treatment System	- 4.16
-Implement Mine Disposal	+ 14.00
-Delete Hydraulic Dredging of Reach C	- 29.02
-Delete Hydraulic Dredging of Reaches B and C	- 40.63
-Obtain On-Site Borrow Material for Construction and Closure of Disposal Site Within the Containment Area (Suitability must be determined)	- 5.09

The degree to which these occur can be minimized by careful monitoring and control of the dredging operation. However, since they will inevitably occur to some extent, dredging and removal can be assumed somewhat less effective than in-place containment.

The effectiveness of any of the alternatives is effected by residual cc tamination which can result from (1) areas of contamination where no direct mitigation is attempted and (2) contamination remaining due to inefficiency in the mitigation technique applied. Obviously if a decision is made not to dredge the lower reaches of IC, the contamination left in this area will reduce the effectiveness of the alternative.

Item 4 pertains strictly to dredging. The degree to which downstream DDTR transport occurs depends on the alternative selected as well as turbidity control at the dredge head. A within-basin diversion will eliminate DDTR transport from the highly contaminated area within the containment dike, but will afford no protection outside the dike. The out-of-basin diversion can eliminate DDTR transport from areas upstream of Dodd Road as well as greatly reduce it below Dodd Road and in IC.

A comparison of effectiveness of alternatives (excluding any consideration of biota contamination) is given in Table 13.

Finally, a key factor is the effectiveness of an alternative in reducing DDTR levels in fish to below the 5 ppm FDA guideline. Unfortunately, this is probably the most difficult measure of effectiveness to predict with accuracy. On the one hand one can state that removal or isolation of a high percentage of the DDTR in the HSB-IC system can, in the long term, only help the situation. Yet because of the high potential for significant fish contamination from even low residual levels of DDTR, one cannot easily predict how quickly positive results can be realized following a clean-up effort.

Several factors should be considered in attempting to judge how long it might take for DDTR levels in fish to be reduced to below 5 ppm. These include current contamination levels, method of contamination, degradation of DDTR by natural processes, effectiveness of DDTR removal, and rate at which fish can excrete or break down DDTR. In Appendix II, Section 5.3, these factors are considered in some depth. Channel catfish in Wheeler Reservoir downstream of IC appear to have DDTR concentrations on the order of 10 ppm due to very low level contamination of either or both sediment and water. Near IC DDTR levels in channel catfish are higher which may be due to higher localized sediment or water DDTR concentrations and/or to migration of fish in and out of IC. Nevertheless, it appears that for channel catfish bioconcentration of DDTR produces fish concentrations in excess of 5 ppm from extremely low environmental concentrations. Hence, it is not reasonable to expect channel catfish DDTR levels to drop below 5 ppm until environmental DDTR levels are reduced below what currently exists in the TR. Presently this level is below what might reasonably be expected to initially remain in IC and HSB after a mitigation alternative was completed. Further, these levels of DDTR in the TR water and sediment would still be present even if a mitigation alternative were completed. Following the completion of

Table 13. Predicted Effectiveness of Mitigation Alternatives

Alternative	Estimated % DDTR: Removed	Estimated % DDTR: Contained In-Place	Estimated % DDTR: Total	Residual Contamination Remaining	Potential for Short-Term Transport During Implementation
A	0	0	0	100%	None
B	99.3	0	99.3	0.7% not isolated plus residual contamination left in all dredging areas	Potential exists during dredging of all areas
C	99.3	0	99.3	0.7% not isolated plus residual contamination left in all dredging areas. All residual contamination subject to low flow and increased sedimentation	Potential reduced or eliminated in Reach A, greatly reduced in Reach B, and reduced in Reach C.
D	4.4	94.9	99.3	0.7% not isolated plus residual contamination left in Reaches B and C. All residual contamination subject to low flow and increased sedimentation.	Potential eliminated in Reach A, greatly reduced in Reach B, and reduced in Reach C.
E	99.3	0	99.3	0.7% not isolated plus residual contamination left in all dredging areas. Residual contamination within diversion dike isolated from HSB flow.	Potential eliminated within containment dike; potential exists during dredging of all other areas.
F	8.3	91.0	99.3	0.7% not isolated plus residual contamination downstream from HSB Mile 3.9. Ponded area within diversion dike isolated from HSB flow.	Potential eliminated within containment dike; potential exists during dredging of all other areas.

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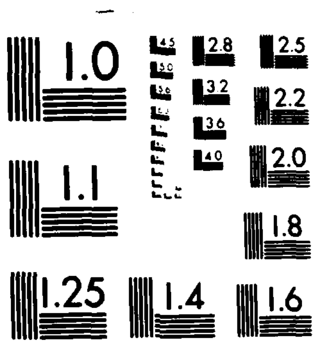

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

Table 13. Predicted Effectiveness of Mitigation Alternatives (Continued, Page 2)

Alternative	Estimated % DDTR[2]			Residual Contamination Remaining	Potential for Short-Term Transport During Implementation
	Removed	Contained In-Place	Total		
F[3]	8.3	91.4	99.7[4]	0.3% not isolated plus residual contamination downstream from HSB Mile 3.9.	Potential eliminated within containment dike; potential exists during dredging of all other areas.

[1] Estimates for action alternatives assume mitigation of contamination, in the noncritical overbank.

[2] Percentage of estimated total, 838 tons.

[3] Using diversion containment area for disposal of dredged material.

[4] Ponded area within containment filled and covered, isolating an additional 0.4%.

any of the alternatives except natural restoration, it is assumed that the flow of DDTR to the TR would be significantly reduced. With little or no "fresh" DDTR entering the river, it could be expected that existing concentrations would go down.

Unfortunately, no data exists regarding natural degradation rates for DDTR under conditions similar to those found in IC and TR. Data for breakdown rates in soils show figures ranging from less than that one year to greater than 30 years depending on a number of conditions. Under the assumption that some mitigation action had essentially eliminated the movement of DDTR from IC to the TR and that natural breakdown in an aquatic environment might roughly parallel breakdown in the soil, significant reductions in DDTR might occur in roughly 1-30 years.

Since the uptake and reduction of DDTR in fish has been shown to occur in significantly shorter time spans than appear to be required for natural degradation of DDTR, it is assumed that the fish are at or near equilibrium with respect to DDTR in the environment. Consequently, one would expect DDTR levels in fish to closely parallel reductions of DDTR in the environment.

If the assumptions and conditions noted above are valid, it might take from a relatively few to 30 or more years for DDTR levels in channel catfish in the TR to drop below the 5 ppm guideline following completion of one of the action alternatives. Further, since any of the action alternatives will leave at least some residual amounts of DDTR in IC above what currently exists in the TR, the channel catfish in IC can be expected to remain contaminated for even longer periods of time.

No difference between the action alternatives can be detailed regarding how quickly DDTR levels in channel catfish in IC and HSB can be reduced.

The natural restoration alternative is predicted to be ineffective in controlling DDTR contamination of the HSB-IC-TR system.